State of South Carolina
Hurricane Evacuation Study – Clearance Times Update

Final Report
February 2012

Northern Conglomerate Transportation Analysis

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South Carolina Hurricane Evacuation Study

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Technical Memorandum

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Executive Summary

The Charleston District, U.S. Army Corps of Engineers (USACE) conducted this study to update hurricane evacuation clearance times for the State of South Carolina's Northern Conglomerate (Horry and Georgetown Counties). The most recent study, completed in April 2000, relied upon 1990 U.S. Census data. This study utilizes 2010 U.S. Census data, where available, and employs similar study methodology used in other recent regional hurricane evacuation study efforts. Recently released 2010 U.S. Census data is available for population and occupied housing units. Tourist and seasonal data relied on the U.S. Census data and hotel/motel inventory and was supplemented by information received from the counties. Demographic changes have occurred in this region as a result of population growth. In addition to population changes, the two study area counties have re-drawn their evacuation zone maps based on updated SLOSH data. The new county evacuation maps incorporate a slightly different configuration of zones that takes into account changes in potential storm surge. Changes in growth, understanding of risk, and areas that need to be evacuated have resulted in clearance time changes for the region.

The transportation analysis process includes five primary steps; the development of evacuation zones and categories, the establishment of an evacuation roadway network, calculating the number of evacuees and vehicles, determining the specific areas evacuees will come from and where they will go, and then routing evacuees along the evacuation roadway network. The analysis section of the report includes separate sub-sections that address how these steps were undertaken, data and assumptions used in the analysis, and other supporting data. The report also includes a study findings section that discusses the development of hurricane evacuation clearance time estimates as well as recommendations for regional traffic control measures to improve evacuation operations. In support of the report, a user-friendly transportation model was developed.

Hurricane evacuation clearance times are provided for Horry and Georgetown counties in the study area. The times were calculated based on traffic congestion levels at principle bottlenecks on the evacuation roadway network. The times include a range of scenarios that take into account tourist occupancy levels (low, medium, high, and extreme), storm intensity scenarios (three different intensity scenarios per county), and response rates (slow, medium, fast and immediate). Impacts were also assessed, as were the potential clearance time benefits associated with the implementation of roadway improvements at key locations.

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I. Introduction

I. Introduction

South Carolina's Northern Conglomerate is at significant risk to impact from hurricanes. Hurricane Irene (2011) revealed the vulnerability of both the urban areas and beach communities in this region and the need to implement effective and timely evacuations.

The last major regional hurricane evacuation transportation analysis to address this area was the *South Carolina Hurricane Evacuation Restudy Transportation Analysis* conducted in April 2000. Other transportation studies that influence this study are listed here:

- *South Carolina Hurricane Evacuation Study-Transportation Analysis (1986)*
- *Hurricane Hugo Post Storm Evacuation Analysis (1989)*
- *Hurricanes Bertha/Fran Post Storm Study (1996)*
- *Hurricane Floyd Post Storm Evacuation Analysis (1999)*
- *North Carolina Hurricane Evacuation Restudy-Transportation Analysis (1999)*
- *South Carolina Hurricane Evacuation Restudy-Transportation Analysis (2000)*
- *US 17/US 521 Contraflow Analysis-Georgetown County (2001)*
- *SC EPD 2000 Census Update of Abbreviated Traffic Model (2002)*
- *Brunswick County Progress Energy Nuclear Power Plant Evacuation Analysis (2002)*
- *Horry County Southern Connector Evacuation Route Analysis (October 2003)*
- *NCDOT Statewide Hurricane Evacuation Model (2005)*
- *I-73 Hurricane Evacuation Alternative Alignments Analysis (2005)*
- *Southern Evacuation Lifeline (SELL) Hurricane Evacuation Analysis (2007*)

This current study builds on recent re-study efforts and incorporates all relevant data included in these other studies.

Figure 1 illustrates the Northern Conglomerate Study Area counties included in this study.

I. Introduction

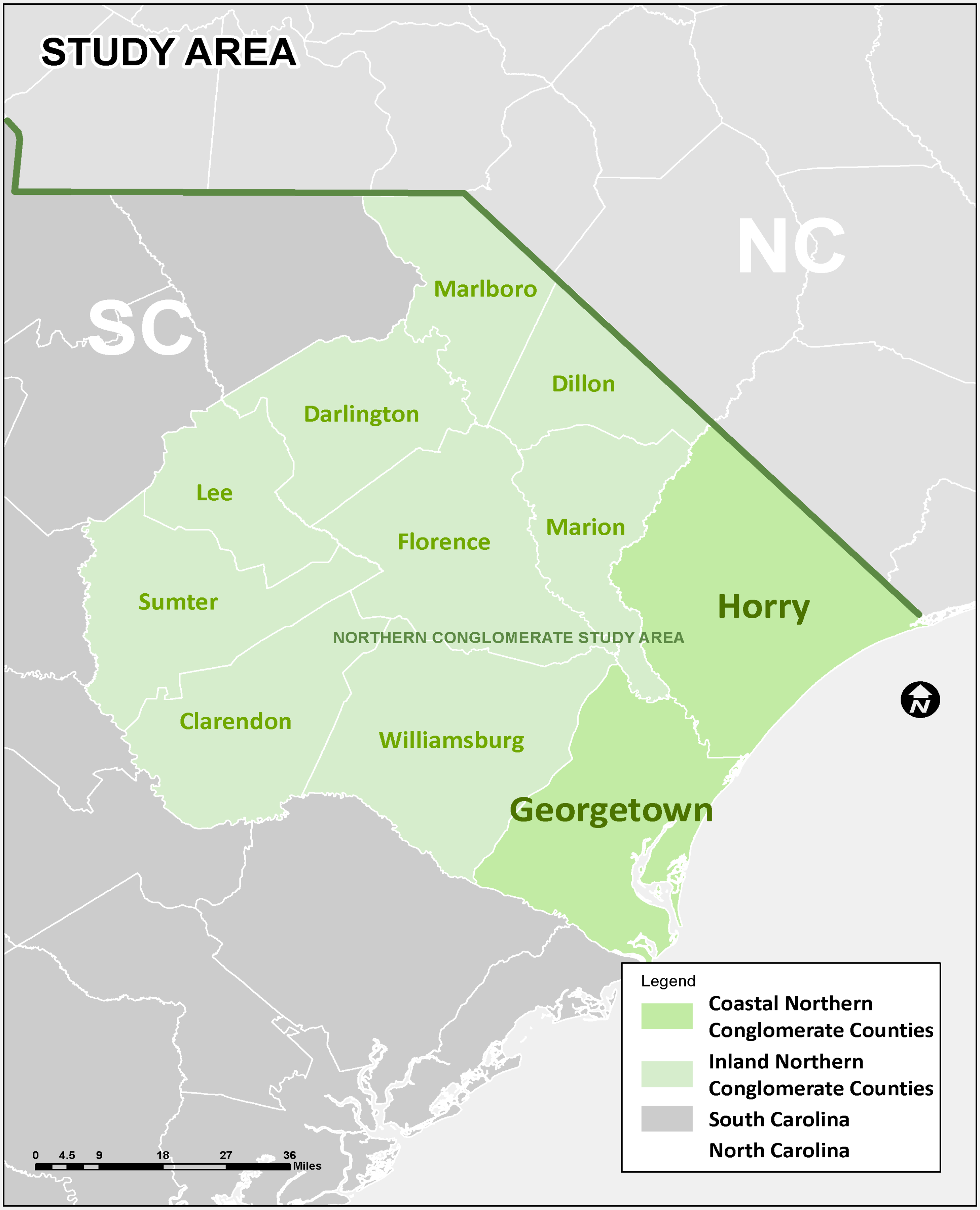

Figure 1: Northern Conglomerate Study Area

II. Project Scope

The project includes a transportation analysis, preparation of evacuation clearance times for inclusion into HURREVAC, and the development of a user-friendly transportation model. The primary purpose of the transportation analysis is to calculate the clearance times needed to conduct a safe and timely evacuation for a range of hurricane threats. Other purposes are to define the evacuation roadway network, to evaluate critical traffic links, and assess the potential impacts of interstate traffic.

The transportation analysis addressed five primary steps:

- developing of evacuation zones and scenarios,
- establishing of an evacuation roadway network,
- calculating the number of evacuees and vehicles,
- conducting evacuee trip generation and assigning destinations, and
- routing evacuees along the evacuation roadway network.

These steps led to the development of study findings, the most important of which are estimates of hurricane evacuation clearance times for Horry and Georgetown counties. The study report provides coverage of these topics as well as information on other evacuation related issues, such as contra flow and sheltering, and recommendations on traffic control measures designed to improve evacuation operations.

The Automated Transportation Model (ATM) developed for the Northern Conglomerate Study Area generates the clearance time results referenced in this document. It was developed in an accessible, user-friendly format to provide users with a streamlined, spreadsheet-based evacuation model that allows real-time sensitivity analyses through the modification of model inputs. The model is structured similarly to those in use in other USACE hurricane evacuation study (HES) areas throughout the United States. A column in the ATM allows users in future years to simply plug in an estimated growth factor to quickly update clearance times and evacuation demand statistics.

The model includes three primary data entry modules (socioeconomic, behavioral and out-route assignment) and three primary data results modules (evacuation statistics, evacuating vehicles and clearance time). While the ATM results have been used to determine the hurricane evacuation clearance times for the study area counties, users have the ability to apply the model to test alternative scenarios as well as adjust data based on changed conditions. Data that may be modified by users include socioeconomic data, behavioral assumptions, roadway segment service volume and traffic routing.

III. Study Analysis

III. Study Analysis

The methodology employed in conducting a hurricane evacuation transportation analysis involves a series of sequential steps. These steps and information related to this study are detailed in this section.

A) Evacuation Zones and Scenarios

The first step in the evacuation planning process involves developing evacuation zones. The evacuation zones for the entire study area were revisited as part of a March 2011 Stakeholder Workshop. The fundamental guidelines for developing zones require developing zones that; reflect risk, are readily understandable, and are easily communicated to the public. For the Northern Conglomerate Study Area, the zone development process started with a review of updated storm surge inundation maps, which were provided by the USACE to identify the areas that could be subject to possible flooding. To make the zones easier to communicate, the evacuation zone boundaries were aligned with key roadway segments where possible.

The county evacuation maps in this study were developed by reviewing the updated county storm surge inundation maps produced by USACE using NOAA's most recent Sea, Lake, and Overland Surge from Hurricanes (SLOSH) model simulations for the Wilmington Basin (2011) (Figure 2). The study area counties used this new data along with zone maps from the earlier study to draw their zonal boundaries. These zones, which were drafted by the study area counties in the March 2011 Stakeholder Workshop and finalized during this study process, are slightly more inclusive in terms of land area than zones used in earlier studies. The new zones provide a more accurate representation of areas that may be at risk to storm surge inundation.

In addition to clarifying the zone maps, the study area counties have also worked to simplify the number and description of their evacuation scenarios. The counties developed a total of three possible evacuation scenarios: Scenario A, Scenario B, and Scenario C as shown in Figures 3 and 4.

Within each scenario for both counties there are additional factors that can be modeled, including variations in tourist occupancy (low – 20%, medium – 50%, high – 70%, and extreme – 85%) and response rate (immediate, rapid, medium and slow). The impact of out-of-region and out-of-state traffic is also evaluated.

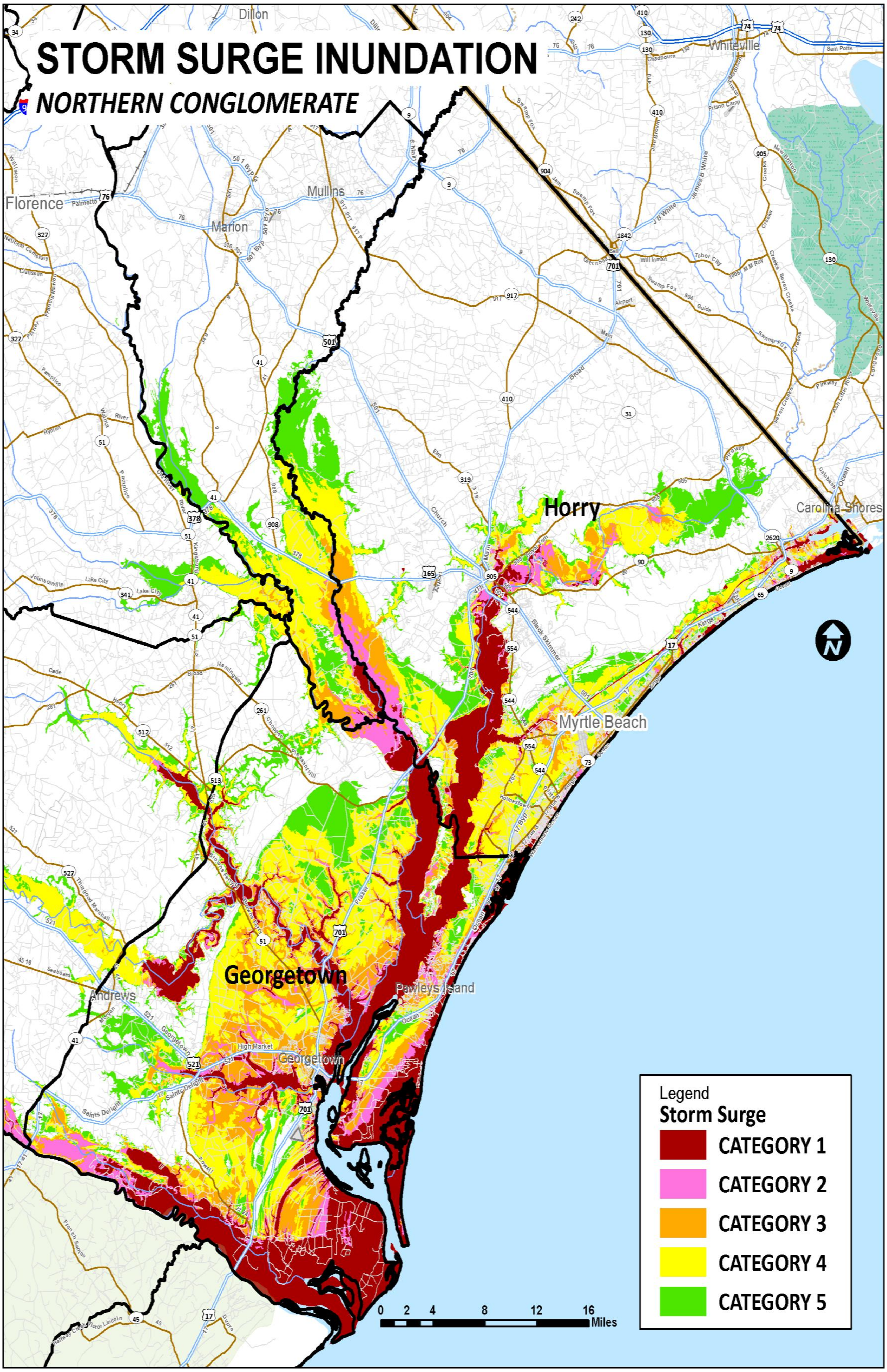

Figure 2: Storm Surge Inundation – Northern Conglomerate

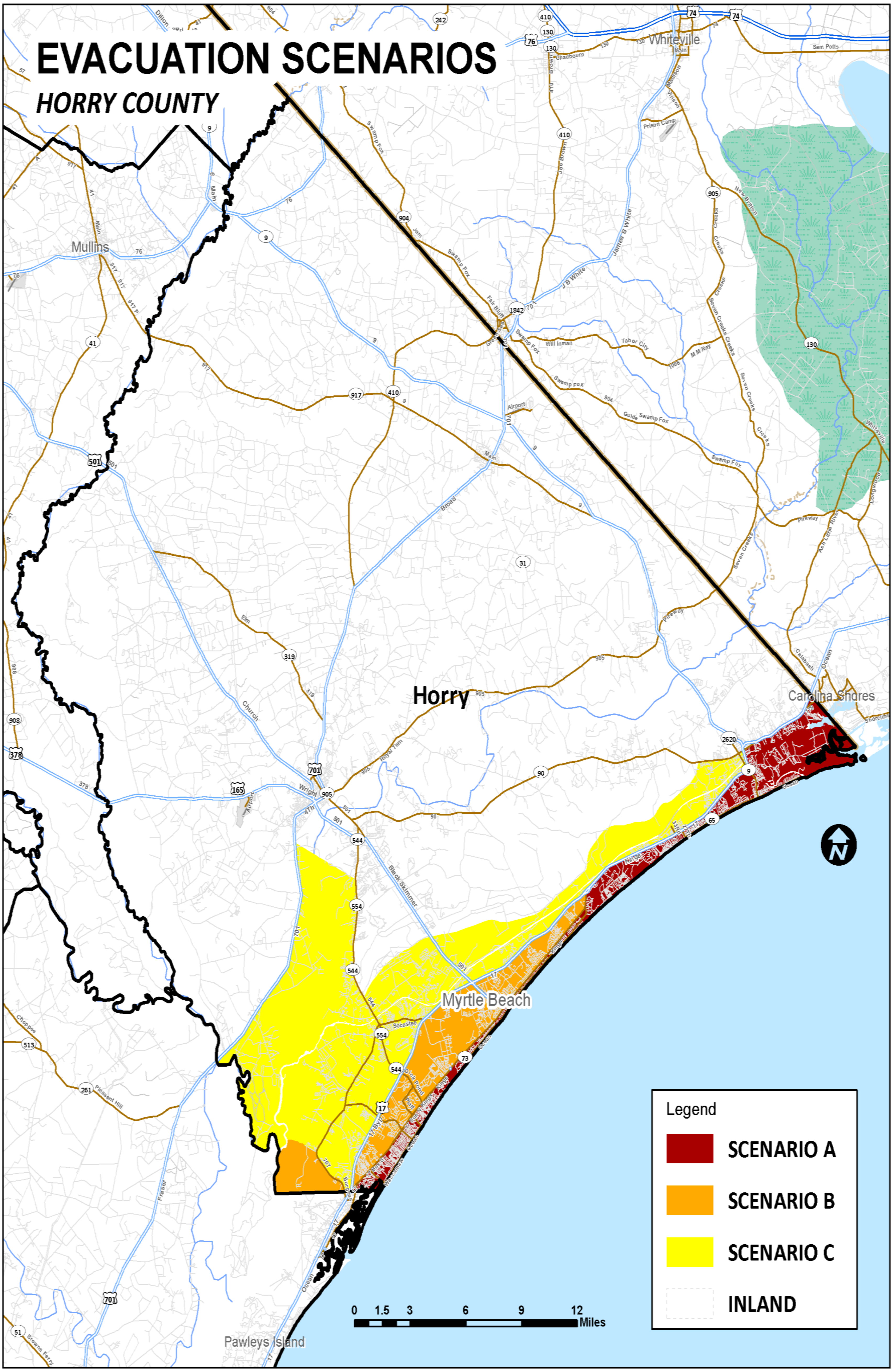

Figure 3: Evacuation Scenarios – Horry County

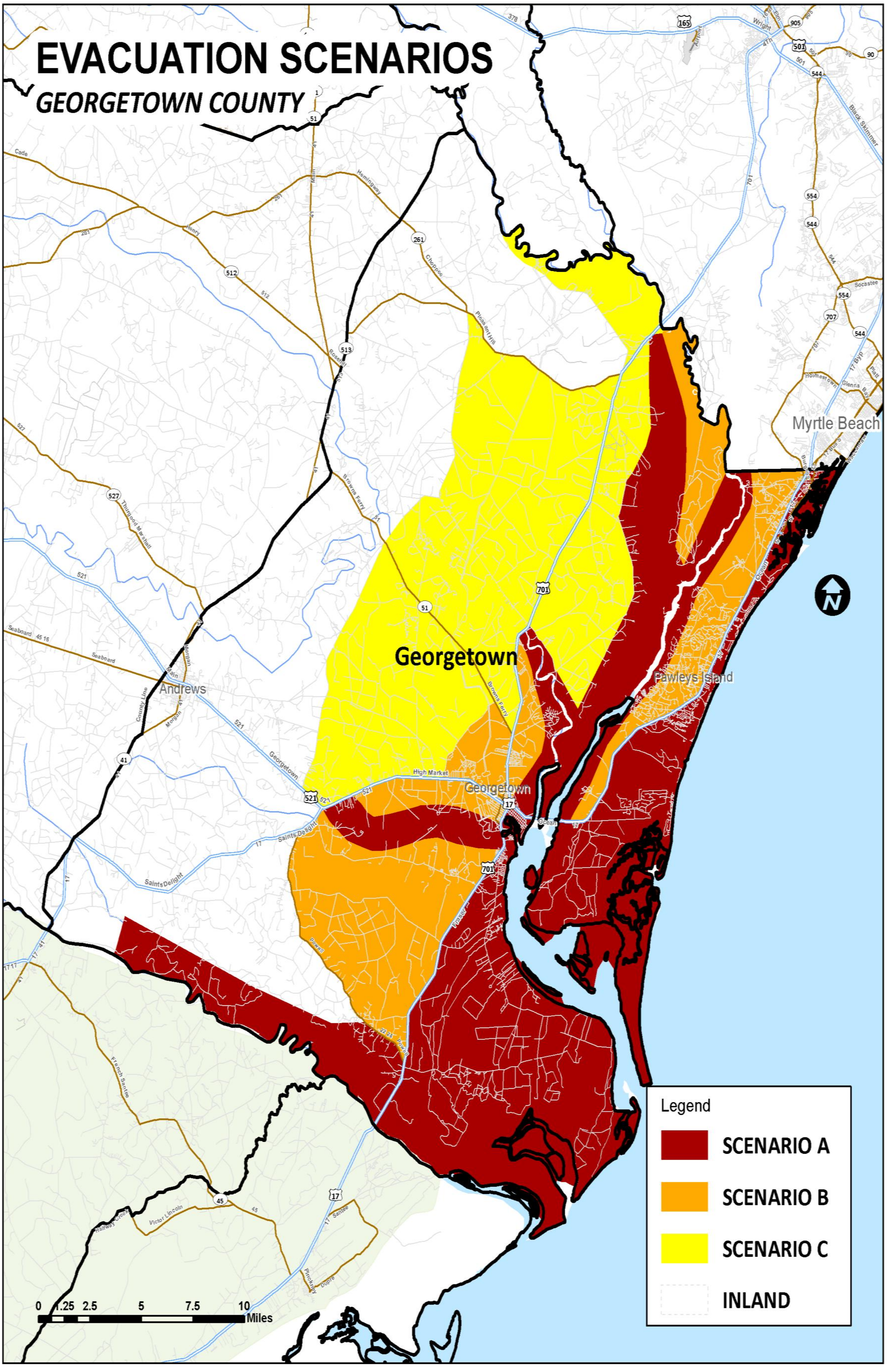

Figure 4: Evacuation Scenarios – Georgetown County

III. Study Analysis

After the zones are developed, they are subdivided into a set of numbered traffic evacuation zones, or TEZs. For this study, the TEZs were based on the census blocks that best correspond to the delineated zone boundaries. These subunits allow for socioeconomic data collection within their boundaries and form the building blocks of the modeling process. The TEZs used in this study align as much as possible with those used in previous study efforts completed for this area. Table 1 shows a detail listing of the TEZ's for Horry and Georgetown Counties.

The descriptions of the Horry County evacuation scenarios are listed below and Figure 5 depicts the TEZs developed for Horry County.

Evacuation Scenario Descriptions – Horry County:

Scenario A (Hurricane Category 1 and 2) includes all areas on and east of US Business 17 (Kings Hwy) up to intersection with US 17 (Kings Hwy) and then all areas on and east of US 17 (Kings Hwy) to the northern county line. Also all flood prone areas on and along the Waccamaw River and the Great and Little Pee Dee Rivers and all mobile homes residents in the county.

Scenario B (Hurricane Category 3) includes all areas on and south of Hwy 707 and Longwood Drive including all areas on and in Longwood Plantation (Blackmoor) to the Waccamaw River and all areas on and east of US 17 By-Pass (Mark Garner Hwy) to US 17 (N. Kings Hwy) and all areas on and east of US 17 (N. Kings Hwy) to the Northern county line. Also all flood prone areas on and along the Waccamaw River and the Great and Little Pee Dee Rivers and all mobile homes residents in the county.

Scenario C (Hurricane Category 4 and 5) includes all areas on and between Hwy 701 and Hwy 544, south of Brown's Chapel Avenue and Hwy 814 plus all areas on and East of Highway 31 (Carolina Bays Pkwy) to Highway 90; and all areas on and East of Highway 90 to Highway 17 and all areas on and east of US 17 to the northern county Line. Also all flood prone areas on and along the Waccamaw River and the Great and Little Pee Dee Rivers and all mobile homes residents in the county.

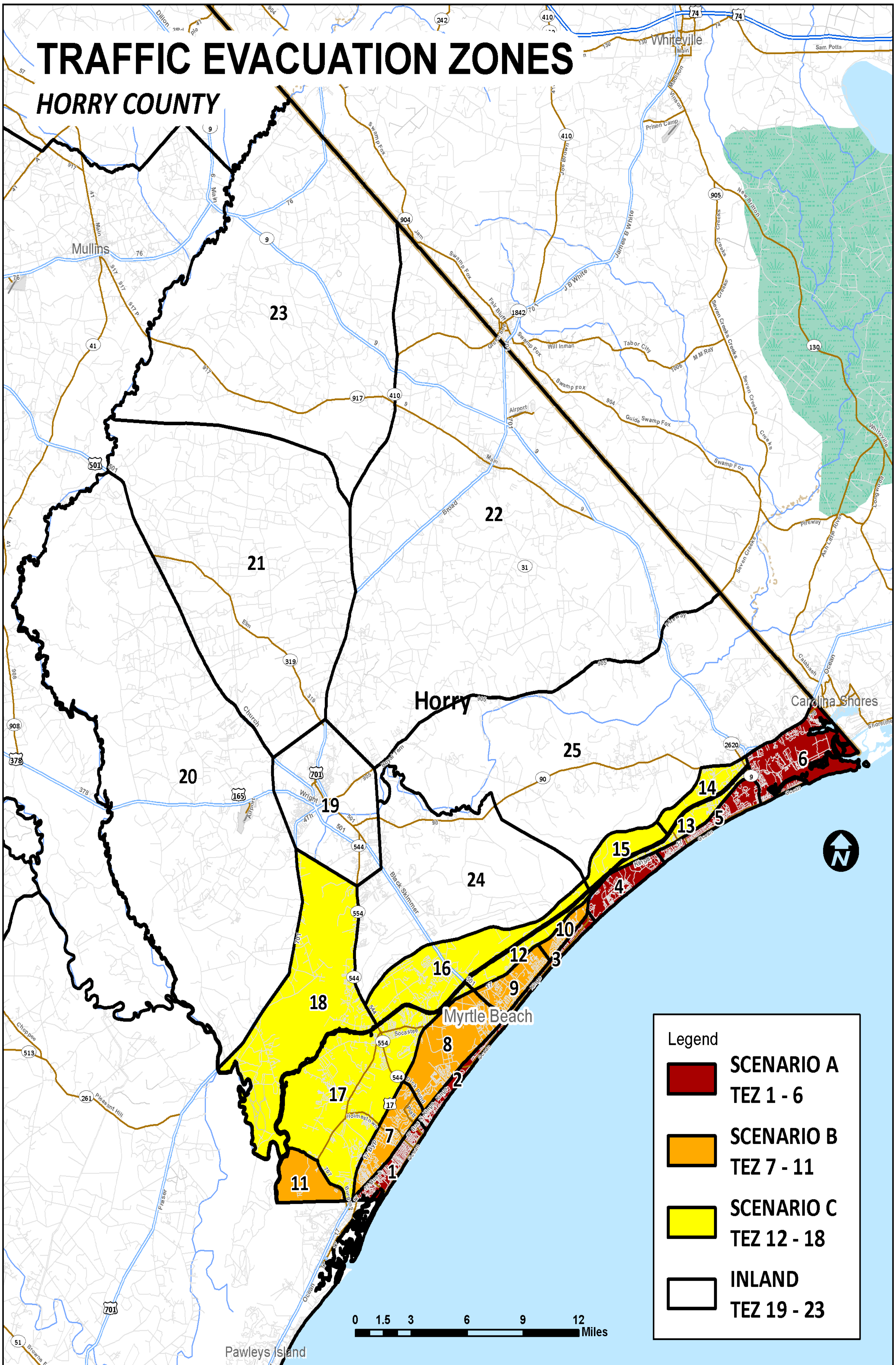

Figure 5: Traffic Evacuation Zones – Horry County

III. Study Analysis

The descriptions of the Georgetown County evacuation scenarios are listed below and Figure 6 depicts the TEZs developed for Georgetown County.

Evacuation Scenario Descriptions – Georgetown County:

Evacuation Zone A - (Cat 1-2) Areas East of Highway 17 to the Atlantic Ocean from the South Santee River and North to the Horry County line, including Sandy Island; areas East of Dawhoo Lake and South of Walker Road and Powell Road to the South Santee River; and all low-lying areas along the Waccamaw River, Great Pee Dee River, Black River, and the Sampit River South of Highway 521 (17A), including Maryville; and all mobile home residents in the County.

Evacuation Zone B - (Cat 3) Areas East of Dawhoo Lake and South of Walker Road to Powell Road to the South Santee River; all areas on the Atlantic side of Powell Road to Alt. US 17 to Highway 521 to Brick Chimney Road to State Highway 51 to Black River Road ending at the Black River; all low-lying areas along the Waccamaw River, Great Pee Dee River, and Black River, and all areas East of them to the coast; and all mobile home residents in the County.

Evacuation Zone C - (Cat4-5) Areas East of Dawhoo Lake and South of Walker Road to Powell Road to the South Santee River; all areas on the Atlantic side of Powell Road to Alt. US 17 to Highway 521 to Sawmill Road to Indian Hut Road to Carvers Bay Road (State Highway S-22-4) to Plantation Hill Road (State Highway 261) to Old Pee Dee Road to the Northern County Line; and all mobile home residents in the County.

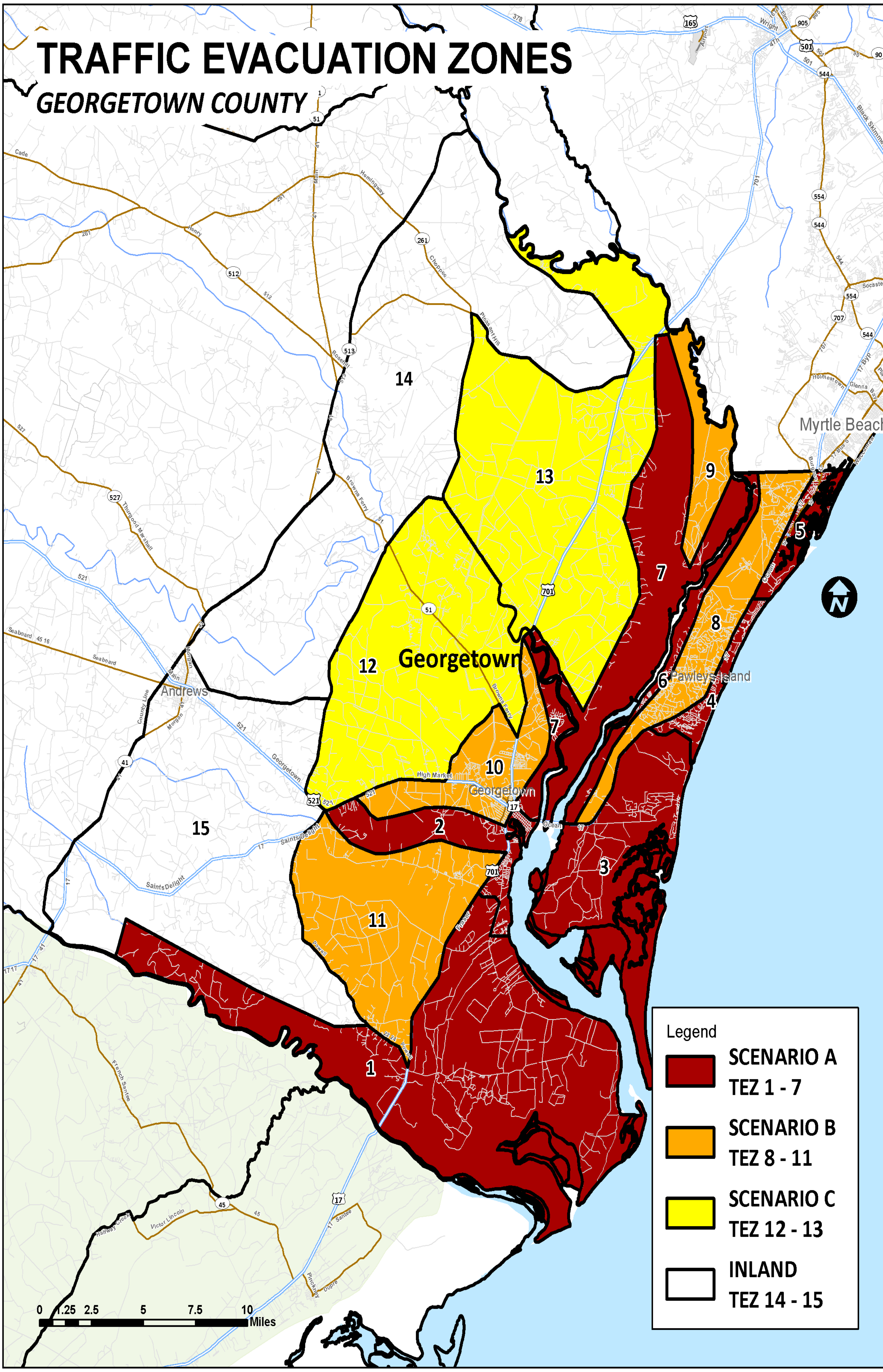

Figure 6: Traffic Evacuation Zones – Georgetown County

Table 1: Traffic Evacuation Zones with Generalized Area Name

County	Evacuation Zones	Map ID	Traffic Evacuation Zone Generalized Area Name
Horry	Scenario A Primary Evacuation Areas	1	1 - Garden City / Surfside Beach
		2	2 - Myrtle Beach State Park
		3	3 - Myrtle Beach
		4	4 - Briarcliffe/Wendy Hill
		5	5 - N Myrtle Beach
		6	6 - Cherry Grove/Little River
	Scenario B Additional Primary Evacuation Areas	7	7 - Garden City/Surfside inland
		8	8 - Myrtle Beach airport
		9	9 - Broadway at the Beach area
		10	10 - The Dunes/Professional Dr
		11	11 - TPC of Myrtle Beach
	Scenario C Additional Primary Evacuation Areas	12	12 - Myrtlewood Golf Club
		13	13 - Barefoot Landing area
		14	14 - Nixons Crossroads
		15	15 - Grand Dunes
		16	16 - Forestbrook
		17	17 - Socastee
		18	18 - Bucksport/Toddville
	Non-Surge Evacuation Areas	19	19 - Conway
		20	20 - Little Pee Dee River
		21	21 - Aynor/Gallivants Ferry
		22	22 - Loris
		23	23 - Duford/nw Horry
		24	24 - Coastal Carolina Univ area
		25	25 - SC 90/Longs/N Waccamaw Riv
Georgetown	Scenario A Primary Evacuation Areas	1	1 - Cat Isl/ Cedar Isl SE area
		2	2 - Sampit Riv/G-town riverine
		3	3 - Debordieu/Wac Neck south
		4	4 - Litchfield/Pawleys Isl
		5	5 - Murrells Inlet
		6	6 - Wac Neck backside riverine
		7	7 - Pee Dee River area
	Scenario B Additional Primary Evacuation Areas	8	8 - Wac neck center
		9	9 - Sandy Island
		10	10 - Georgetown inland area
		11	11 - Gtown airport/north Santee
	Scenario C Additional Primary Evacuation Areas	12	12 - Black River/SC 51 central area
		13	13 - Plantersville/Yauhannah
	Non-Surge Evacuation Areas	14	14 - Outland/northwest inland
		15	15 - Andrews/southwest inland

B) Evacuation Roadway Network

The second stage in the evacuation modeling process involves identifying the evacuation roadway network. The network is limited to the primary evacuation routes that evacuees will use to travel from the risk areas. The evacuation roadway network does not include all the local roads in the Northern Conglomerate counties, only those roadways which are likely to convey a significant number of evacuating vehicles which have been aggregated from adjoining local roads. The network used in this study reflects the primary routes that the South Carolina Department of Transportation (SCDOT) and the SC Department of Public Safety – Highway Patrol has identified in their public education materials and state highway maps. In addition to these official routes, a few additional roadway segments were included for the purposes of transportation modeling, including a limited number of additionally modeled routes. The network, including the additional modeled segments, was reviewed by area stakeholders and revisions and updates were made based on their comments. The evacuation network map for Horry and Georgetown Counties is shown in Figure 7.

Once established, the network is divided into a series of segments, or road links, which are bounded by nodes represented on the maps by dots. As part of the modeling process, data is collected regarding these links and roadway segments, including directional service volume and average daily trip information.

The heavy traffic demands on a highway's normal capacity during an evacuation has encouraged South Carolina emergency managers, law enforcement, and transportation officials to consider methods to enhance the capacity of existing roadways, including contra flowing traffic. Using their experiences with actual evacuations for major Hurricanes Hugo in 1989 and Floyd in 1999 (as well as a host of other less significant events), South Carolina has developed the operational procedures for contra flowing US 501 from the Conway Bypass to Marion. They have also eased the US 501 bottleneck between SC 544 and Conway using contra flow. Other segments are being considered and will be implemented pending further study and available resources.

The implementations of the contra flow segments are critical to the region for reducing overall clearance times in the northern conglomerate. However, with the SC 544/US 501 enhancement, a larger portion of evacuation traffic is shifted to US 378 which is still a two lane rural highway in many locations. The state is aggressively working to widen and improve the US 378 corridor. Until US 378 is able to accommodate two westbound lanes of evacuation traffic all the way to Lake City and Turbeville, clearance times will not be reduced dramatically. It should be noted that the behavioral analysis performed by the University of South Carolina (*2011 South Carolina Hurricane Evacuation Behavioral Study*) showed that, of the sample, US 378 is not a preferred evacuation route as their escape route. This means that those forced to use the route will need good instructions en route so that they can get to their intended destination. Since US 378 was not listed in the behavioral survey results as a preferred evacuation route by the public, and since many will be forced by current reverse lane operations to use that route, it is presumed that users will be unfamiliar with the route and thus will need en route messages to help direct them to I-95 and inland destinations.

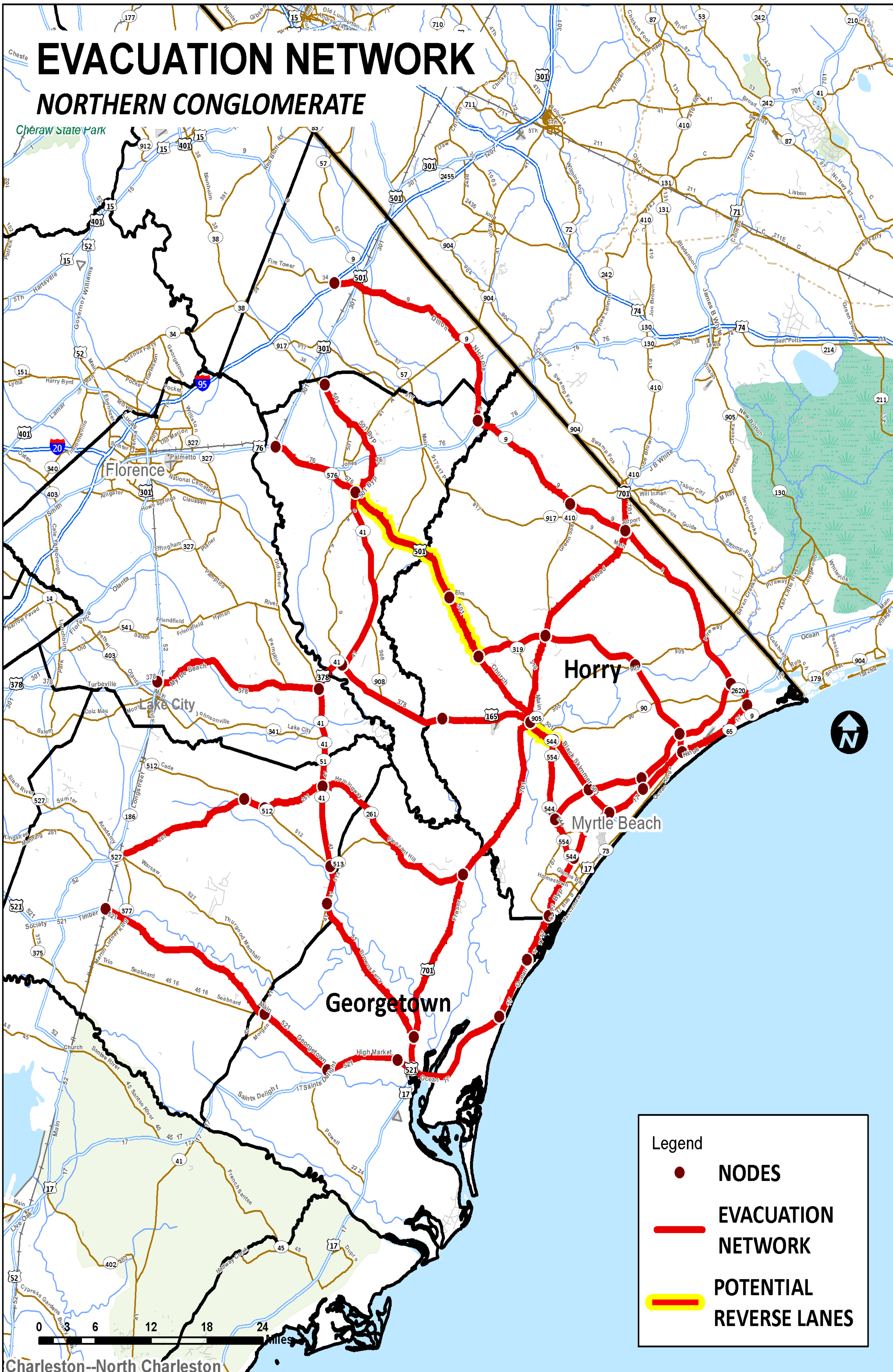

Figure 7: Traffic Evacuation Network – Northern Conglomerate

III. Study Analysis

As noted, the evacuation roadway network was developed based on routes that SCDOT and the SC Department of Public Safety – Highway Patrol have promoted as logical evacuation choices and, for the most part, are included in public brochures. Key regional connectors were added to the network for the purposes of modeling expected evacuee route choices and traffic movements. The network was reviewed and revised throughout the study process and allows for the testing of contra flow benefits.

Table 2 lists the critical roadway segments and the estimated initial service volume at the commencement of the evacuation.

III. Study Analysis

Table 2: Critical Roadway Segments

County	Critical Roadway Segments	Directional Service Volume	Number of Lanes *(Both Directions)*	AADT*
Horry	US 17 sb into Georgetown County	1,600	4	14,800
	US 378 wb out of Conway** **NO REVERSAL**	1,800	4	11,200
	US 378 wb inland 2 lane section** **NO REVERSAL**	1,100	2	7,700
	US 501 nb e of SC 31/Carolina Bays Pkwy	2,400	4	52,000
	US 501 e of SC 544 at outlet mall area	1,700	4	47,000
	US 501 from SC 544 to Conway** **NO REVERSAL**	1,700	4	46,800
	US 501 from Conway to Conway Bypass** **NO REVERSAL**	1,800	4	21,500
	US 501 from Conway Bypass through Aynor** **NO REVERSAL**	1,800	4	11,100
	US 501 from Aynor to SC 576 at Marion** **NO REVERSAL**	2,200	4	14,800
	Conway Bypass	2,800	4	21,500
	SC 9 at Longs	1,800	4	21,000
	SC 9 from Green Sea to Nichols	1,200	2	4,500
	US 701 nb out of county	1,200	2	7,900
	US 17 nb into NC	2,000	4	22,000
	SC 544 from Socastee to US 501	1,700	4	26,900
	Grissom Pkwy at SC 31/Carolina Bays Pkwy	1,000	4	13,600
	SC 31/Carolina Bays Pkwy sb at US 501	3,000	6	18,300
	SC 31/Carolina Bays Pkwy nb at SC 22	3,000	6	21,400
Georgetown	US 17 Bridge off Waccamaw Neck	1,700	4	24,600
	Church St at Fraser St in Georgetown	1,500	4	24,600
	US 521 from Georgetown to Alt US 17	1,700	4	8,400
	US 521 wb west of Andrews	1,200	2	10,200
	Alt US 17 sb at SC 41	1,000	2	2,400
	SC 261 wb at Hemingway	1,000	2	5,100
	SC 41/SC 51 nb at Kingsburg	700	2	7,100

*AADT – Annual Average Daily Traffic = total yearly volume divided by the number of days in a year.
**Regional critical roadway segments.

C) Socioeconomic Data

The third stage of the planning process involves determining how many people are evacuating. This is achieved by collecting demographic data on permanent residents and tourists from the U.S. Census and other state and local sources. The collection of socioeconomic data for this effort focused largely on collecting best available dwelling unit data for each county from a number of sources. With the US Census having not released some of its sub county level data at the time the analysis was performed, this part of the study was challenging. Dwelling unit data required for the transportation analysis includes permanent occupied units, mobile homes, and seasonal units. Seasonal units must include hotel/motels, seasonal condo/timeshares, and RV/campground spaces to get an accurate picture of seasonal population that might need to evacuate along with the permanent residents. Population and dwelling unit estimates were made using data collected from; the 2010 US Census, hotel motel inventories, the 2007 SELL corridor study, and coordination efforts with county offices. The following provides a synopsis of the key dwelling unit variables:

Horry County permanent occupied units and population — Permanent occupied housing units and population numbers came directly from the 2010 Census data. The ATM numbers also match the 2010 Census data.

Horry County mobile home units — The 2000 census reported 24,666 mobile homes countywide, the 2009 American Community Survey (ACS) estimated 28,048 mobile homes and the 2010 Census just reported 29,055 mobile homes. The factored SELL project mobile home data included approximately 30,000 units. A somewhat higher estimate of 32,900 mobile homes was used in the model which provides a buffer for those units that the Census and other sources typically miss. The growth of mobile homes in the county has been rapidly increasing as more traditional homes have become too expensive for many residents and service workers. It should be noted that the Vulnerability report mobile home data for Horry is a total of 24,121 mobile homes and includes only those mobile homes for which the county had geo-coded addresses which could be compared against SLOSH surge areas in the vulnerability analysis. As the county updates its mobile home data base in future years, the numbers can be easily incorporated into the new ATM.

Horry County seasonal/tourist units — As mentioned previously, seasonal units must include hotel-motels units, seasonal condo/timeshare/houses, and RV campground slots to get an accurate picture of Horry County's seasonal population. The census provides a seasonal/recreational use vacant unit count which gets at everything except hotel motel units and campgrounds. The 2000 Census reports 24,936 seasonal/vacant units, the 2009 ACS estimated 57,864 vacant and seasonal units, and the 2010 census just reported 49,862 seasonal units. In addition 47,000 hotel motel units and 7,477 campground sites not included in the census vacant seasonal numbers were identified. The contractor did extensive internet searches for each hotel, motel, bed and breakfast, and campground to verify location, and number of rooms/campsites. In addition to the company/hotel's official websites for each location, hotels.com, expedia.com, and Travelocity.com were also consulted to obtain the best data for tourist units. Recognizing that many of the seasonal units are in foreclosure, this study settled on a figure of just under 84,000 seasonal units countywide in the ATM and this compares favorably with the agreed upon and heavily scrutinized number from the SELL project.

Georgetown County permanent occupied units and population — The 2010 Census numbers were used directly and the ATM number matches the 2010 Census.

Georgetown mobile home units — Mobile home numbers in the vulnerability report match county data provided by the emergency management office. This study used the same data as a base and included a few more mobile home units in outlying areas of the county based on available census data. The vulnerability report estimated 6,817 mobile home units. The 2000 Census reported 6,878 mobile homes and the 2009 ACS estimated 6,932 mobile homes countywide in Georgetown County. The census tends to be slightly low so this study incorporated just over 7,300 units in the ATM. Historically the census mobile home numbers are lower than the number of mobile home units that counties and state data centers report. Two of the many reasons are 1) the census reports mobile homes that are permanent residences and some mobile homes are actually seasonal by nature; 2) mobile home counts are often tied to paid registrations (mobile home tags are renewed annually like vehicles) and a portion of some rural area residents don't keep paid renewals up to date.

Georgetown seasonal/tourist units — For Georgetown County, the 2000 Census reports 6,623 seasonal/vacant units and the 2009 ACS estimated 10,954 vacant and seasonal units. The new 2010 census figure is 5,112 seasonal unit numbers. Over and above the census figures, the contractor used online sources to identify additional hotel/motel data which included some 1,820 hotel/motel units not including campgrounds. The local Chamber provided some seasonal unit data for the Wacammaw Neck that focused on Pawleys Island (approximately 2200 units). The vulnerability study combined the chamber of commerce and hotel data to arrive at 4,904 geo-codable seasonal units. This transportation study used a figure of just over 10,000 seasonal unit's county wide in the ATM and this appears reasonable in light of the countywide data.

Northern Conglomerate Inland County Mobile Homes — 2010 Census numbers were used to obtain total mobile homes for Clarendon, Darlington, Dillon, Florence, Lee, Marlboro, Mario, Sumter, and Williamsburg Counties.

Tables 3 and 4 identify the socioeconomic data used for estimating the population for Horry and Georgetown Counties and the total number of vehicles. Table 5 identifies the vulnerable mobile homes and evacuating vehicles located in the nearby inland counties which were also included in this study. The inland county data reflected in Table 5 was developed by applying unique county-by-county vehicles per mobile home number to the latest mobile home count. A vehicle usage figure of 70 percent was then applied based on historical behavioral data. A participation rate was then applied based on the scenario. This parameter was varied between 50% for Scenario A, 70% for Scenario B, and 100% for Scenario C. These are very conservative assumptions based on prior experience with multiple post storm evacuation assessments where inland counties were interviewed. Most of the inland county evacuees will go to the home of a friend or relative, a church, or a local public shelter. Trip movements are generally off the primary evacuation network and do not traverse the critical bottlenecks which control clearance time closer to the coast. This has been consistent in each of the historical HES studies for the study area and Hugo/Bertha/Floyd post storm assessments. The ATM has an inland county module which has the specific parameters and formulas for each county.

Behavioral assumptions are also incorporated to help determine the actual participation rates of individual and vehicle usage. The combination of demographic data interpreted in light of behavioral assumptions allows the modelers to identify the appropriate number of vehicles that will be loading the evacuation roadway network from each numbered zone in each scenario.

Table 3: Socioeconomic Data – Population by Evacuation Zones

County	Evacuation Zone	Permanent Occupied Housing Units*	People per Permanent Occupied Housing Units	Population Permanent Occupied Housing Units	Mobile Home Units*	People per Mobile Home Units	Population Mobile Home Units	Seasonal / Tourist Units*	People per Seasonal / Tourist Units	Population Seasonal / Tourist Units
Horry	Scenario A Primary Evacuation Areas	13,870	2.03	28,303	4,596	2.03	9,445	60,998	3.00	182,994
	Scenario B Additional Primary Evacuation Areas	17,614	2.21	39,111	3,141	2.21	7,153	10,189	3.00	30,567
	Scenario C Additional Primary Evacuation Areas	29,798	2.29	70,992	7,220	2.29	17,389	9,267	3.00	27,801
	Non-Surge Evacuation Areas	50,930	2.59	130,855	18,018	2.59	46,443	3,376	3.00	10,128
	Total	**112,212**		**269,261**	**32,975**		**80,430**	**83,830**		**251,490**
Georgetown	Scenario A Primary Evacuation Areas	7,747	2.34	18,015	1,620	2.34	3,810	8,044	3.00	24,132
	Scenario B Additional Primary Evacuation Areas	9,688	2.57	23,188	2,195	2.57	5,319	1,775	3.00	5,325
	Scenario C Additional Primary Evacuation Areas	2,353	2.64	6,229	1,220	2.64	3,229	196	3.00	588
	Non-Surge Evacuation Areas	4,749	2.69	12,757	2,339	2.69	6,227	240	3.00	720
	Total	**24,537**		**60,189**	**7,374**		**18,585**	**10,255**		**30,765**

*See important notes in previous section *C) Socioeconomic Data* regarding county specific numbers and differences between these numbers and those shown in the vulnerability analysis.

Table 4: Vehicle Ownership Data – Vehicles by Evacuation Zones

County	Evacuation Zone	Permanent Occupied Housing Units*	Vehicles per Permanent Occupied Housing Units	Vehicles Permanent Occupied Housing Units	Mobile Home Units*	Vehicles per Mobile Home Units*	Vehicles Mobile Home Units	Seasonal / Tourist Units*	Vehicles per Seasonal / Tourist Units	Vehicles Seasonal / Tourist Units
Horry	Scenario A Primary Evacuation Areas	13,870	1.60	22,387	4,596	1.60	7,320	60,998	1.05	64,048
	Scenario B Additional Primary Evacuation Areas	17,614	1.59	27,453	3,141	1.59	4,914	10,189	1.05	10,698
	Scenario C Additional Primary Evacuation Areas	29,798	1.63	49,455	7,220	1.63	11,861	9,267	1.05	9,730
	Non-Surge Evacuation Areas	50,930	1.73	87,054	18,018	1.73	30,992	3,376	1.05	3,545
	Total	**112,212**		**186,349**	**32,975**		**55,087**	**83,830**		**88,021**
Georgetown	Scenario A Primary Evacuation Areas	7,747	1.73	13,230	1,620	1.73	2,826	8,044	1.05	8,446
	Scenario B Additional Primary Evacuation Areas	9,688	1.59	15,471	2,195	1.59	3,521	1,775	1.05	1,864
	Scenario C Additional Primary Evacuation Areas	2,353	1.51	3,633	1,220	1.51	1,883	196	1.05	206
	Non-Surge Evacuation Areas	4,749	1.59	7,580	2,339	1.59	3,723	240	1.05	252
	Total	**24,537**		**39,914**	**7,374**		**11,953**	**10,255**		**10,768**

*See important notes in previous section *C) Socioeconomic Data* regarding county specific numbers and differences between these numbers and those shown in the vulnerability analysis.

Table 5: Inland County Data

Inland County	Mobile Home Units	Evacuating Vehicles		
		Scenario A	Scenario B	Scenario C
Clarendon	7,465	3,998	5,597	7,995
Darlington	8,705	4,814	6,739	9,628
Dillon	5,019	2,547	3,566	5,094
Florence	12,735	7,087	9,922	14,174
Lee	2,000	1,099	1,539	2,198
Marlboro	2,890	1,366	1,912	2,731
Marion	3,958	1,967	2,754	3,934
Sumter	12,066	6,757	9,460	13,514
Williamsburg	7,880	2,637	3,692	5,274
Total	**62,718**	**32,272**	**45,181**	**64,542**

III. Study Analysis

Evacuees and Vehicles

The number of evacuees and vehicles in this study was calculated based on best available data. Socioeconomic data was collected from secondary sources by the contractor. A separate, study-specific behavioral analysis was conducted as part of the overall HES study effort.

The primary source of behavioral data *used for this transportation analysis* was the *2011 South Carolina Hurricane Evacuation Behavioral Study*, conducted by the University of South Carolina. The study, helped in determining a number of the modeling parameters used in the transportation analysis.

Secondary behavioral sources included:

- Other recently completed National Hurricane Program (NHP) Hurricane Evacuation Studies (HES) (Mississippi, Alabama),
- Input from State and local governments.

Tables 6 and 7 identify the behavioral assumptions related to evacuee participation and vehicle usage respectively. As noted, these assumptions are derived from those employed in recent studies and validated in post storm analyses. All assumptions were reviewed in light of the results of the recently completed University of South Carolina Study.

For Table 6, the following assumptions were made:

- Scenario A Evacuation Zones are closest to the coast, and therefore 100% evacuee participation is assumed.

- In Scenario B Evacuation Zones, there is lesser participation in lower category storms, but participation rates increase as the storm intensity increases. While there may be less participation in lower category storms, participation rates increase as the storm intensity increases, and may be 100% in the higher category storms.

- Scenario C Evacuation Zones follow a similar pattern as Scenario B evacuees with less participation in lower category storms and increasing participation in higher category storms, and may be 100% in the higher category storms.

For Table 7, the following assumptions were made:

- Seasonal and tourist units will utilize 100% of their vehicles for evacuation purposes.
- Permanent and mobile home units use 65% to 75% of the vehicles available to them. Factors may include fear of separation among family members.
- Zones closest to the coast have slightly higher vehicle utilization than those further inland.

Evacuation numbers assume a 100% participation rate for those areas being told to evacuate. Previous studies were used to determine the estimated number of out-of-state vehicles that would impact this study area. The number of inland mobile homes is a very small portion of Georgetown County's evacuation population and therefore slightly backing down the mobile home participation for Scenario A would be almost inconsequential. This means that there is a slight conservative bias for the Georgetown evacuation statistics. Table 7 identifies the total number of evacuees and Table 8 identifies the evacuating vehicles by traffic evacuation zone anticipated in each modeled scenario.

While the recent University of South Carolina (USC) behavioral survey was reviewed in the conduct of the analysis, behavioral survey results are not used directly as the modeled evacuation rates. As noted previously, it is imperative that any modeling approach ensure the safety of evacuees. As such, all individuals who reside in areas that should evacuate in any given scenario are modeled accordingly. This results in a 100 percent participation rate for surge areas, an approach that is consistent with all previously conducted USACE studies. Modeled participation rates for risk areas outside of the primary surge area decline according to reduction in risk, with inland areas exhibiting the lowest levels of participation. The modeling approach also includes some level of participation from areas outside of the primary evacuation zone to account for shadow evacuees.

As noted, the 100 percent participation rate was used for the surge evacuation areas with a much lower rate applied to (non mobile home) inland non-surge evacuation areas. A slightly larger participation rate was applied to Horry County Scenario B zones versus the Georgetown County Scenario B zones since the Horry County "B" zones are more coastal in nature (these evacuees are only several blocks from the beach in many cases). Most of the Georgetown Scenario B zone population lives in the town of

Georgetown well away from the immediate coast (thus tempering expected participation).

It should be recognized that behavioral research, including the USC study, often indicate a much lower participation rate in areas subject to storm surge, ranging from 50 percent in low category storms, up to 80 to 90 percent in high category storms. Wisely, the purpose of a clearance times is to provide emergency managers with the full operational period in which an evacuation must occur if everyone who should evacuate does so. It should be noted that the ATM provided as part of the study provides emergency managers with the ability to quickly modify participation rates for additional behavioral scenarios.

Table 6: Evacuee Participation

County	Evacuation Zone	Scenario A			Scenario B			Scenario C		
		Perm Occ Units	Mobile Home Units	Tourist Units	Perm Occ Units	Mobile Home Units	Tourist Units	Perm Occ Units	Mobile Home Units	Tourist Units
Horry	Scenario A Primary Evacuation Areas	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Scenario B Additional Primary Evacuation Areas	2%	90%	50%	100%	100%	100%	100%	100%	100%
	Scenario C Additional Primary Evacuation Areas	2%	90%	50%	5%	95%	80%	100%	100%	100%
	Non-Surge Evacuation Areas	2%	70%	50%	5%	90%	80%	10%	100%	80%
Georgetown	Scenario A Primary Evacuation Areas	100%	100%	100%	100%	100%	100%	100%	100%	100%
	Scenario B Additional Primary Evacuation Areas	2%	100%	50%	100%	100%	100%	100%	100%	100%
	Scenario C Additional Primary Evacuation Areas	2%	100%	50%	5%	100%	80%	100%	100%	100%
	Non-Surge Evacuation Areas	2%	100%	50%	5%	100%	80%	10%	100%	100%

Table 7: Evacuee Vehicle Usage Rates

County	Evacuation Zone	Vehicle Usage % for Permanent Units	Vehicle Usage % for Mobile Home Units	Vehicle Usage % for Tourist Units
Horry	Scenario A Primary Evacuation Areas	75%	75%	100%
	Scenario B Additional Primary Evacuation Areas	70%	70%	100%
	Scenario C Additional Primary Evacuation Areas	65%	65%	100%
	Non-Surge Evacuation Areas	65%	65%	100%
Georgetown	Scenario A Primary Evacuation Areas	75%	75%	100%
	Scenario B Additional Primary Evacuation Areas	65%	65%	100%
	Scenario C Additional Primary Evacuation Areas	65%	65%	100%
	Non-Surge Evacuation Areas	65%	65%	100%

Table 8: Evacuating People Statistics

County	Evacuation Zone	Scenario A				Scenario B				Scenario C			
		Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ
Horry	Scenario A Primary Evacuation Areas	74,052	101,500	156,399	183,848	74,052	101,500	156,399	183,848	74,052	101,500	156,399	183,848
	Scenario B Additional Primary Evacuation Areas	10,897	13,189	17,774	20,068	46,753	51,339	60,508	65,093	46,753	51,339	60,508	65,093
	Scenario C Additional Primary Evacuation Areas	20,198	22,281	26,451	28,537	24,761	28,096	34,769	38,106	77,942	82,113	90,454	94,622
	Non-Surge Evacuation Areas	35,465	36,223	37,743	38,502	48,045	49,260	51,692	52,907	56,910	58,125	60,555	61,770
	Total	**140,612**	**173,193**	**238,367**	**270,955**	**193,611**	**230,195**	**303,368**	**339,954**	**255,657**	**293,077**	**367,916**	**405,333**
Georgetown	Scenario A Primary Evacuation Areas	24,045	27,664	34,902	38,521	24,046	27,667	34,907	38,526	24,046	27,667	34,907	38,526
	Scenario B Additional Primary Evacuation Areas	6,342	6,741	7,539	7,940	24,519	25,318	26,915	27,715	24,519	25,318	26,915	27,715
	Scenario C Additional Primary Evacuation Areas	3,363	3,407	3,495	3,539	3,497	3,567	3,708	3,779	6,375	6,464	6,641	6,729
	Non-Surge Evacuation Areas	6,496	6,550	6,658	6,712	6,744	6,831	7,004	7,091	7,105	7,213	7,428	7,537
	Total	**40,246**	**44,362**	**52,594**	**56,712**	**58,806**	**63,383**	**72,534**	**77,111**	**62,045**	**66,662**	**75,891**	**80,507**

Table 9: Evacuating Vehicle Statistics

County	Evacuation Zone	Scenario A				Scenario B				Scenario C			
		Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ
Horry	Scenario A Primary Evacuation Areas	32,801	42,409	61,624	71,230	32,801	42,409	61,624	71,230	32,801	42,409	61,624	71,230
	Scenario B Additional Primary Evacuation Areas	4,750	5,552	7,156	7,958	21,892	23,496	26,706	28,310	21,892	23,496	26,706	28,310
	Scenario C Additional Primary Evacuation Areas	8,643	9,374	10,833	11,563	10,491	11,660	13,994	15,163	34,579	36,039	38,957	40,417
	Non-Surge Evacuation Areas	15,273	15,539	16,071	16,337	20,661	21,085	21,937	22,363	24,496	24,922	25,774	26,199
	Total	**61,467**	**72,874**	**95,684**	**107,088**	**85,845**	**98,650**	**124,261**	**137,066**	**113,768**	**126,866**	**153,061**	**166,156**
Georgetown	Scenario A Primary Evacuation Areas	12,032	13,300	15,832	17,099	12,034	13,302	15,835	17,101	12,034	13,302	15,835	17,101
	Scenario B Additional Primary Evacuation Areas	2,677	2,816	3,095	3,236	10,522	10,801	11,362	11,640	10,522	10,801	11,362	11,640
	Scenario C Additional Primary Evacuation Areas	1,272	1,287	1,319	1,334	1,322	1,347	1,397	1,421	2,412	2,444	2,505	2,536
	Non-Surge Evacuation Areas	2,502	2,520	2,558	2,577	2,595	2,626	2,686	2,716	2,733	2,772	2,847	2,885
	Total	**18,483**	**19,923**	**22,804**	**24,246**	**26,473**	**28,076**	**31,280**	**32,878**	**27,701**	**29,319**	**32,549**	**34,162**

D) Trip Generation and Destinations

The next stage of the process requires an understanding of the destinations that individual evacuees will travel to. Destinations in the transportation modeling are defined as: in county public shelters, in county friends/relatives, in county hotel motels, and out of county. While the behavioral analysis is helpful in discerning destination patterns, it is unreliable for specific percentages. People are twice as likely to say they will go to a public shelter as actually go to one. People assume that hotel motel space will be available locally when most will close or not be available. Churches also play a big role in this area and are part of the friends/relative percentage for modeling purposes. This study relies on both current behavioral and past post storm evacuation parameters in the modeling. It is as much an art as science to correctly gauge and apply behavioral assumptions correctly. Fortunately, many studies have been documented for this exact area and provide a basis for the behavioral tendencies of the populations. The ATM, produced as a part of this study, allows the modification of destination percentages where someone may have a different scenario they would like to test.

Destinations for evacuees from the study area’s two counties will depend on the perceived risk from the approaching storm. Larger, more intense hurricanes may drive evacuees further inland as they attempt to get out of harm’s way. The percentage of individuals heading to each of these specific destinations is applied to the total number of individuals in each numbered TEZ. This allows the total number of vehicles going to each destination to be calculated. Table 10 identifies the anticipated destination percentages of evacuees in each modeled scenario.

The shelter destination included in the model relates to self evacuees (those individuals who can get into a car and evacuate) and represent potential demand, regardless of the available capacity. Tables 11 and 12 identify the number of people and vehicles going to public shelter. Tables 13 through 15 identify the number of vehicles traveling to friends or relatives, hotels or motels, and out of area destinations.

Table 10: Evacuee Destination Percentages

County	Evacuation Zone	Percent To Public Shelters			Percent To Friends / Relatives			Percent To Hotels / Motels			Percent To Out of Area		
		Scen A	Scen B	Scen C	Scen A	Scen B	Scen C	Scen A	Scen B	Scen C	Scen A	Scen B	Scen C
Horry	Scenario A Primary Evacuation Areas	5%	5%	5%	50%	40%	30%	5%	5%	5%	40%	50%	60%
	Scenario B Additional Primary Evacuation Areas	7%	7%	7%	58%	48%	38%	0%	0%	0%	35%	45%	55%
	Scenario C Additional Primary Evacuation Areas	12%	12%	12%	58%	48%	38%	0%	0%	0%	30%	40%	50%
	Non-Surge Evacuation Areas	15%	15%	20%	65%	55%	40%	0%	0%	0%	20%	30%	40%
Georgetown	Scenario A Primary Evacuation Areas	5%	5%	5%	50%	40%	30%	5%	5%	5%	40%	50%	60%
	Scenario B Additional Primary Evacuation Areas	7%	7%	7%	58%	48%	38%	0%	0%	0%	35%	45%	55%
	Scenario C Additional Primary Evacuation Areas	12%	12%	12%	58%	48%	38%	0%	0%	0%	30%	40%	50%
	Non-Surge Evacuation Areas	15%	15%	15%	65%	55%	45%	0%	0%	0%	20%	30%	40%

Table 11: Evacuating People to Public Shelters

County	Evacuation Zone	Scenario A				Scenario B				Scenario C			
		Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ
Horry	Scenario A Primary Evacuation Areas	1,874	2,146	2,696	2,971	1,874	2,146	2,696	2,971	1,874	2,146	2,696	2,971
	Scenario B Additional Primary Evacuation Areas	533	556	603	625	2,815	2,860	2,951	2,998	2,815	2,860	2,951	2,998
	Scenario C Additional Primary Evacuation Areas	2,040	2,063	2,103	2,125	2,359	2,394	2,461	2,493	8,589	8,630	8,714	8,754
	Non-Surge Evacuation Areas	5,143	5,149	5,166	5,173	6,924	6,935	6,960	6,972	10,998	11,009	11,034	11,046
	Total	**9,590**	**9,914**	**10,568**	**10,894**	**13,972**	**14,335**	**15,068**	**15,434**	**24,276**	**24,645**	**25,395**	**25,769**
Georgetown	Scenario A Primary Evacuation Areas	961	996	1,069	1,105	961	996	1,069	1,105	961	996	1,069	1,105
	Scenario B Additional Primary Evacuation Areas	404	409	416	419	1,637	1,644	1,659	1,668	1,637	1,644	1,659	1,668
	Scenario C Additional Primary Evacuation Areas	395	395	397	397	407	407	409	409	749	750	751	753
	Non-Surge Evacuation Areas	962	962	963	964	991	992	994	995	1,040	1,042	1,044	1,044
	Total	**2,722**	**2,762**	**2,845**	**2,885**	**3,996**	**4,039**	**4,131**	**4,177**	**4,387**	**4,432**	**4,523**	**4,570**

Table 12: Evacuating Vehicles to Public Shelters

County	Evacuation Zone	Scenario A Low Occ	Scenario A Med Occ	Scenario A High Occ	Scenario A Extreme Occ	Scenario B Low Occ	Scenario B Med Occ	Scenario B High Occ	Scenario B Extreme Occ	Scenario C Low Occ	Scenario C Med Occ	Scenario C High Occ	Scenario C Extreme Occ
Horry	Scenario A Primary Evacuation Areas	1,000	1,097	1,288	1,383	1,000	1,097	1,288	1,383	1,000	1,097	1,288	1,383
	Scenario B Additional Primary Evacuation Areas	252	261	277	285	1,372	1,388	1,421	1,436	1,372	1,388	1,421	1,436
	Scenario C Additional Primary Evacuation Areas	903	912	925	932	1,044	1,056	1,080	1,092	3,881	3,897	3,926	3,940
	Non-Surge Evacuation Areas	2,228	2,232	2,237	2,240	3,000	3,005	3,013	3,017	4,765	4,768	4,777	4,783
	Total	**4,383**	**4,502**	**4,727**	**4,840**	**6,416**	**6,546**	**6,802**	**6,928**	**11,018**	**11,150**	**11,412**	**11,542**
Georgetown	Scenario A Primary Evacuation Areas	517	530	555	568	517	530	555	568	517	530	555	568
	Scenario B Additional Primary Evacuation Areas	174	175	178	180	708	711	716	719	708	711	716	719
	Scenario C Additional Primary Evacuation Areas	150	150	150	150	154	155	155	155	284	284	285	285
	Non-Surge Evacuation Areas	371	371	371	371	382	383	383	383	401	402	402	402
	Total	**1,212**	**1,226**	**1,254**	**1,269**	**1,761**	**1,779**	**1,809**	**1,825**	**1,910**	**1,927**	**1,958**	**1,974**

Table 13: Evacuating Vehicles to Friends / Relatives

County	Evacuation Zone	Scenario A				Scenario B				Scenario C			
		Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ
Horry	Scenario A Primary Evacuation Areas	8,396	8,396	8,396	8,396	6,716	6,716	6,716	6,716	5,037	5,037	5,037	5,037
	Scenario B Additional Primary Evacuation Areas	1,979	1,979	1,979	1,979	9,224	9,224	9,224	9,224	7,303	7,303	7,303	7,303
	Scenario C Additional Primary Evacuation Areas	4,309	4,309	4,309	4,309	4,103	4,103	4,103	4,103	12,216	12,216	12,216	12,216
	Non-Surge Evacuation Areas	9,639	9,639	9,639	9,639	10,974	10,974	10,974	10,974	9,516	9,516	9,516	9,516
	Total	**24,323**	**24,323**	**24,323**	**24,323**	**31,017**	**31,017**	**31,017**	**31,017**	**34,072**	**34,072**	**34,072**	**34,072**
Georgetown	Scenario A Primary Evacuation Areas	4,961	4,961	4,961	4,961	3,968	3,968	3,968	3,968	2,977	2,977	2,977	2,977
	Scenario B Additional Primary Evacuation Areas	1,417	1,417	1,417	1,417	4,827	4,827	4,827	4,827	3,822	3,822	3,822	3,822
	Scenario C Additional Primary Evacuation Areas	723	723	723	723	615	615	615	615	897	897	897	897
	Non-Surge Evacuation Areas	1,605	1,605	1,605	1,605	1,400	1,400	1,400	1,400	1,201	1,201	1,201	1,201
	Total	**8,706**	**8,706**	**8,706**	**8,706**	**10,810**	**10,810**	**10,810**	**10,810**	**8,897**	**8,897**	**8,897**	**8,897**

Table 14: Evacuating Vehicles to Hotels / Motels

		Scenario A				Scenario B				Scenario C			
County	Evacuation Zone	Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ
Horry	Scenario A Primary Evacuation Areas	840	840	840	840	840	840	840	840	840	840	840	840
	Scenario B Additional Primary Evacuation Areas	0	0	0	0	0	0	0	0	0	0	0	0
	Scenario C Additional Primary Evacuation Areas	0	0	0	0	0	0	0	0	0	0	0	0
	Non-Surge Evacuation Areas	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**840**	**840**	**840**	**840**	**840**	**840**	**840**	**840**	**840**	**840**	**840**	**840**
Georgetown	Scenario A Primary Evacuation Areas	496	496	496	496	496	496	496	496	496	496	496	496
	Scenario B Additional Primary Evacuation Areas	0	0	0	0	0	0	0	0	0	0	0	0
	Scenario C Additional Primary Evacuation Areas	0	0	0	0	0	0	0	0	0	0	0	0
	Non-Surge Evacuation Areas	0	0	0	0	0	0	0	0	0	0	0	0
	Total	**496**	**496**	**496**	**496**	**496**	**496**	**496**	**496**	**496**	**496**	**496**	**496**

Table 15: Evacuating Vehicles to Out of Area

County	Evacuation Zone	Scenario A				Scenario B				Scenario C			
		Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ
Horry	Scenario A Primary Evacuation Areas	22,568	32,079	51,100	60,613	24,247	33,758	52,780	62,292	25,925	35,438	54,460	63,971
	Scenario B Additional Primary Evacuation Areas	2,517	3,312	4,901	5,696	11,296	12,883	16,062	17,650	13,217	14,805	17,983	19,573
	Scenario C Additional Primary Evacuation Areas	3,433	4,156	5,599	6,322	5,345	6,501	8,815	9,971	18,481	19,926	22,816	24,262
	Non-Surge Evacuation Areas	3,404	3,668	4,195	4,458	6,688	7,108	7,951	8,373	10,216	10,637	11,480	11,902
	Total	**31,922**	**43,215**	**65,795**	**77,089**	**47,576**	**60,250**	**85,608**	**98,286**	**67,839**	**80,806**	**106,739**	**119,708**
Georgetown	Scenario A Primary Evacuation Areas	6,059	7,312	9,820	11,075	7,052	8,306	10,815	12,068	8,044	9,298	11,806	13,061
	Scenario B Additional Primary Evacuation Areas	1,086	1,225	1,500	1,640	4,986	5,263	5,817	6,094	5,992	6,269	6,822	7,099
	Scenario C Additional Primary Evacuation Areas	400	415	445	461	553	577	626	651	1,232	1,262	1,323	1,354
	Non-Surge Evacuation Areas	525	544	581	600	814	844	903	933	1,131	1,168	1,243	1,280
	Total	**8,070**	**9,496**	**12,346**	**13,776**	**13,405**	**14,990**	**18,161**	**19,746**	**16,399**	**17,997**	**21,194**	**22,794**

III. Study Analysis

A subcomponent of trip distribution involves identifying destinations that evacuees may seek, including public shelter. Behavioral research and actual experience indicates that nationally, some evacuees may indeed seek out public shelter rather than the home of a friend or relative or a hotel motel during an actual evacuation. Destination percentages identified in the University of South Carolina behavioral study as well as those employed in the most recent South Carolina Hurricane Evacuation Study and studies conducted throughout the southeast, were reviewed and applied in establishing the destination percentages used for this analysis. This data provides officials with an idea of the potential demand they might expect to encounter in an actual evacuation so that they can plan accordingly.

Table 16 lists public shelter data provided by state and local officials, including their location and, where available, their capacity. Table 17 displays public shelter demand, derived from destination selection data in the transportation model.

Table 16: Public Shelters

County	Shelter Name	Address	City	Zip	Capacity	TEZ
Horry	Conway Elementary*	1101 Snowhill Drive	Conway	29526	683	19
	Conway High School	2301 Church Street	Conway	29526	1,280	19
	Whittmore Park Middle School	1808 Rhue Street	Conway	29527	845	19
	Pee Dee Elementary School	6555 Highway 134	Conway	29527	533	20
	South Conway Elementary School*	3001 Fourth Avenue	Conway	29526	495	20
	Aynor High School	201 Highway 24	Aynor	29511	627	20
	Aynor Elementary	516 Jordanville Road	Aynor	29511	413	21
	Loris Elementary	901 E Highway 9 Business	Loris	29569	464	22
	Loris High School	301 Loris Lions Road	Loris	29569	1,090	22
	Green Sea Floyds Elementary	5000 Tulip Grove Road	Green Sea	29545	533	23
	Green Sea Floyds High & Middle Schools	5265 Highway 9	Green Sea	29545	1,115	23
	Total				**8,078**	
Georgetown	Pleasant Hill Elementary	127 Schoolhouse Drive	Hemingway	29554	622	14
	Carvers Bay High School	13000 Chopee Road	Georgetown	29440	690	14
	Andrews Elementary School	13072 County Line Road	Andrews	29510	930	15
	Andrews High School	201 South Maple	Andrews	29510	318	15
	Total				**2,560**	

* The Conway and South Conway Elementary Schools facilities provided by Horry County are located in the Scenario C surge area and are therefore not included in the capacity estimates for evacuation zone Scenario C, as presented in Table 17.
Note: Any specific shelter data or list is subject to change and may not reflect actual shelters employed.

Table 17: Public Shelter Demand (in People)

County	Shelter	Scenario A				Scenario B				Scenario C			
		Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ
Horry	Shelter Demand	9,590	9,914	10,568	10,894	13,972	14,335	15,068	15,434	24,276	24,645	25,395	25,769
	Shelter Capacity	8,078	8,078	8,078	8,078	8,078	8,078	8,078	8,078	6,900	6,900	6,900	6,900
	Deficit / Surplus	**-1,512**	**-1,836**	**-2,490**	**-2,816**	**-5,894**	**-6,257**	**-6,990**	**-7,356**	**-17,376**	**-17,745**	**-18,495**	**-18,869**
Georgetown	Shelter Demand	2,722	2,762	2,845	2,885	3,996	4,039	4,131	4,177	4,387	4,432	4,523	4,570
	Shelter Capacity	2,560	2,560	2,560	2,560	2,560	2,560	2,560	2,560	2,560	2,560	2,560	2,560
	Deficit / Surplus	**-162**	**-202**	**-285**	**-325**	**-1,436**	**-1,479**	**-1,571**	**-1,617**	**-1,827**	**-1,872**	**-1,963**	**-2,010**

Note: Shelter capacity estimates are intended to provide a general overview of potential space surpluses or deficits when projected demand is reviewed in light of available identified spaces. Capacity figures are subject to change. Any specific shelter data or list is subject to change and may not reflect actual shelters employed.

III. Study Analysis

An analysis was conducted to estimate the potential number of vehicles and evacuees travelling from the Northern Conglomerate to Columbia, SC, Charlotte, NC, and Fayetteville, NC – three of the region's main urban areas likely to receive evacuees. A set of tables has been developed showing estimates of destination percentages by out route, as well as the total number of vehicles and evacuees by out route in various storm scenarios. This information can provide emergency managers along the listed out routes and in these inland cities with valuable data to prepare for the potential impacts of an evacuation.

E) Inland City Destinations / Evacuees

Table 18 provides an estimate of traffic volumes in various storm scenarios by primary study area out routes for evacuees heading to three regional destinations; Columbia, SC, Charlotte, NC and Fayetteville, NC. A destination percentage by out route for each of the three inland cities was developed by the transportation contractor based on their unique understanding of the study area and best professional judgment and is presented. Tables 19 and 20 show data on the portion of vehicles and evacuees that may be expected along each listed out route based on the destination percentage estimates in Table 18 at each of the three destination cities for six different evacuation scenarios.

Table 18: Inland Destinations – Total Traffic Volume on Exit Route and Percentage to Inland City

Total Exiting Vehicles by Route					
	US 521	**US 378**	**US 501**	**SC 9**	**US 701**
Scenario A low tourist occupancy	8,056	5,897	18,812	7,100	1,537
Scenario A high tourist occupancy	14,676	12,967	44,824	15,500	3,768
Scenario B low tourist occupancy	13,732	9,807	28,540	9,300	2,293
Scenario B high tourist occupancy	21,349	18,362	57,677	18,400	4,784
Scenario C low tourist occupancy	16,565	18,020	42,848	12,500	2,989
Scenario C high tourist occupancy	24,227	26,863	72,402	21,700	5,527
Percent to Columbia	**20%**	**20%**	**18%**	**15%**	**0%**
Scenario A low tourist occupancy	8,056	5,897	18,812	7,100	1,537
Scenario A high tourist occupancy	14,676	12,967	44,824	15,500	3,768
Scenario B low tourist occupancy	13,732	9,807	28,540	9,300	2,293
Scenario B high tourist occupancy	21,349	18,362	57,677	18,400	4,784
Scenario C low tourist occupancy	16,565	18,020	42,848	12,500	2,989
Scenario C high tourist occupancy	24,227	26,863	72,402	21,700	5,527
Percent to Charlotte	**10%**	**10%**	**15%**	**15%**	**0%**
Scenario A low tourist occupancy	8,056	5,897	18,812	7,100	1,537
Scenario A high tourist occupancy	14,676	12,967	44,824	15,500	3,768
Scenario B low tourist occupancy	13,732	9,807	28,540	9,300	2,293
Scenario B high tourist occupancy	21,349	18,362	57,677	18,400	4,784
Scenario C low tourist occupancy	16,565	18,020	42,848	12,500	2,989
Scenario C high tourist occupancy	24,227	26,863	72,402	21,700	5,527
Percent to Fayetteville	**5%**	**5%**	**7%**	**8%**	**30%**

Table 19: Inland Destinations – Vehicles

Hypothetical Inland City Destinations/Evacuees Generated by Northern Conglomerate Number of Vehicles Attracted from Study Area Exit Routes						
Inland City/Scenario						**Inland City Totals by Scenario**
Columbia, SC	**US 521**	**US 378**	**US 501**	**SC 9**	**US 701**	
Scenario A low tourist occupancy	1,611	1,179	3,386	1,065	0	**7,242 vehicles**
Scenario A high tourist occupancy	2,935	2,593	8,068	2,325	0	**15,922 vehicles**
Scenario B low tourist occupancy	2,746	1,961	5,137	1,395	0	**11,240 vehicles**
Scenario B high tourist occupancy	4,270	3,672	10,382	2,760	0	**21,084 vehicles**
Scenario C low tourist occupancy	3,313	3,604	7,713	1,875	0	**16,505 vehicles**
Scenario C high tourist occupancy	4,845	5,373	13,032	3,255	0	**26,505 vehicles**
Charlotte, NC						
Scenario A low tourist occupancy	806	590	2,822	1,065	0	**5,282 vehicles**
Scenario A high tourist occupancy	1,468	1,297	6,724	2,325	0	**11,813 vehicles**
Scenario B low tourist occupancy	1,373	981	4,281	1,395	0	**8,030 vehicles**
Scenario B high tourist occupancy	2,135	1,836	8,652	2,760	0	**15,383 vehicles**
Scenario C low tourist occupancy	1,657	1,802	6,427	1,875	0	**11,761 vehicles**
Scenario C high tourist occupancy	2,423	2,686	10,860	3,255	0	**19,242 vehicles**
Fayetteville, NC						
Scenario A low tourist occupancy	403	295	1,317	568	461	**3,044 vehicles**
Scenario A high tourist occupancy	734	648	3,138	1,240	1,130	**6,890 vehicles**
Scenario B low tourist occupancy	687	490	1,998	744	688	**4,607 vehicles**
Scenario B high tourist occupancy	1,067	918	4,037	1,472	1,435	**8,930 vehicles**
Scenario C low tourist occupancy	828	901	2,999	1,000	897	**6,625 vehicles**
Scenario C high tourist occupancy	1,211	1,343	5,068	1,736	1,658	**11,017 vehicles**

Table 20: Inland Destinations – People

Hypothetical Inland City Destinations/Evacuees Generated by Northern Conglomerate Number of People Attracted from Study Area Exit Routes						
Inland City/Scenario						**Inland City Totals by Scenario**
Columbia, SC	**US 521**	**US 378**	**US 501**	**SC 9**	**US 701**	
Scenario A low tourist occupancy	3,384	2,477	7,111	2,237	0	**15,208 people**
Scenario A high tourist occupancy	6,164	5,446	16,943	4,883	0	**33,436 people**
Scenario B low tourist occupancy	5,767	4,119	10,788	2,930	0	**23,604 people**
Scenario B high tourist occupancy	8,967	7,712	21,802	5,796	0	**44,277 people**
Scenario C low tourist occupancy	6,957	7,568	16,197	3,938	0	**34,660 people**
Scenario C high tourist occupancy	10,175	11,282	27,368	6,836	0	**55,661 people**
Charlotte, NC						
Scenario A low tourist occupancy	1,692	1,238	5,926	2,237	0	**11,092 people**
Scenario A high tourist occupancy	3,082	2,723	14,120	4,883	0	**24,807 people**
Scenario B low tourist occupancy	2,884	2,059	8,990	2,930	0	**16,863 people**
Scenario B high tourist occupancy	4,483	3,856	18,168	5,796	0	**32,304 people**
Scenario C low tourist occupancy	3,479	3,784	13,497	3,938	0	**24,697 people**
Scenario C high tourist occupancy	5,088	5,641	22,807	6,836	0	**40,371 people**
Fayetteville, NC						
Scenario A low tourist occupancy	846	619	2,765	1,193	968	**6,392 people**
Scenario A high tourist occupancy	1,541	1,362	6,589	2,604	2,374	**14,469 people**
Scenario B low tourist occupancy	1,442	1,030	4,195	1,562	1,445	**9,674 people**
Scenario B high tourist occupancy	2,242	1,928	8,479	3,091	3,014	**18,753 people**
Scenario C low tourist occupancy	1,739	1,892	6,299	2,100	1,883	**13,913 people**
Scenario C high tourist occupancy	2,544	2,821	10,643	3,646	3,482	**23,135 people**

F) Trip Assignment

Once the total number of vehicles evacuating from each zone in each scenario is established, each individual trip must be routed along the evacuation roadway network. In the modeling process, each trip is meticulously routed through the evacuation roadway appropriate for that trip. For the Northern Conglomerate Area, evacuating traffic was routed along the most accessible out routes from or through each county, paying attention to logical route selections. Trips are attenuated on the network by incorporating evacuation traffic for all destination types on routes close to the surge areas and Conway and then using only out of county trips on segments leading out of the counties.

In the model, every TEZ is assigned its own unique combination of out routes by percentage of its evacuating vehicles leaving the region. The out-of-region evacuating vehicles from each TEZ are then aggregated on each out route to determine the total vehicle demand for the region on those roadways. In this manner, each key roadway segment on an evacuation corridor is assigned a total number of vehicles by evacuation scenario.

Using data from the recent evacuation studies, knowledge of the study area, and professional judgment, vehicle movements were calculated to determine the estimated number of vehicles from each TEZ that would be utilizing each modeled roadway segment. The specific routing determinations, for each modeled link when viewed in the context of total demand versus capacity, allows for an understanding of congestion by modeled roadway segment. The underlying data, including a GIS map layer of the roadway network by segment, as well as a data table that contains directional service volumes and the total number of vehicles by roadway segment in each modeled scenario, has been provided as part of this report. Figure 8 depicts the relative congestion by roadway segment for Horry and Georgetown Counties in a worst case evacuation scenario. Figure 9 depicts the relative congestion by roadway segment for Horry and Georgetown Counties in a worst case evacuation scenario impact with the potential contra flow. Table 21 provides a listing of the worst case evacuation network congestion for each modeled/critical roadway segment as well as directional service volume which indicates the amount of traffic that can be processed per hour at the start of an evacuation.

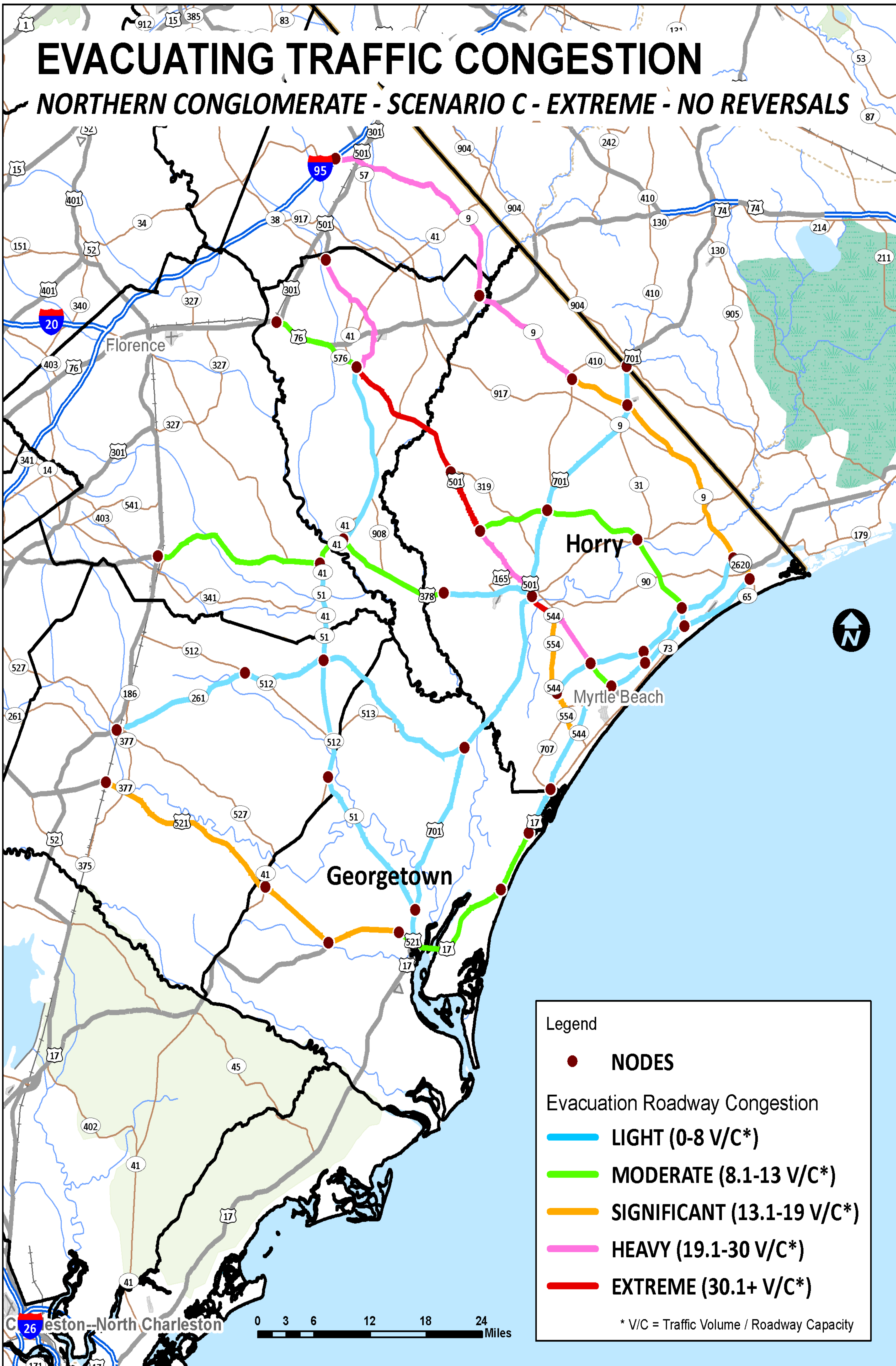

Figure 8: Worst Case Evacuating Traffic Congestion – Northern Conglomerate / No Reversals

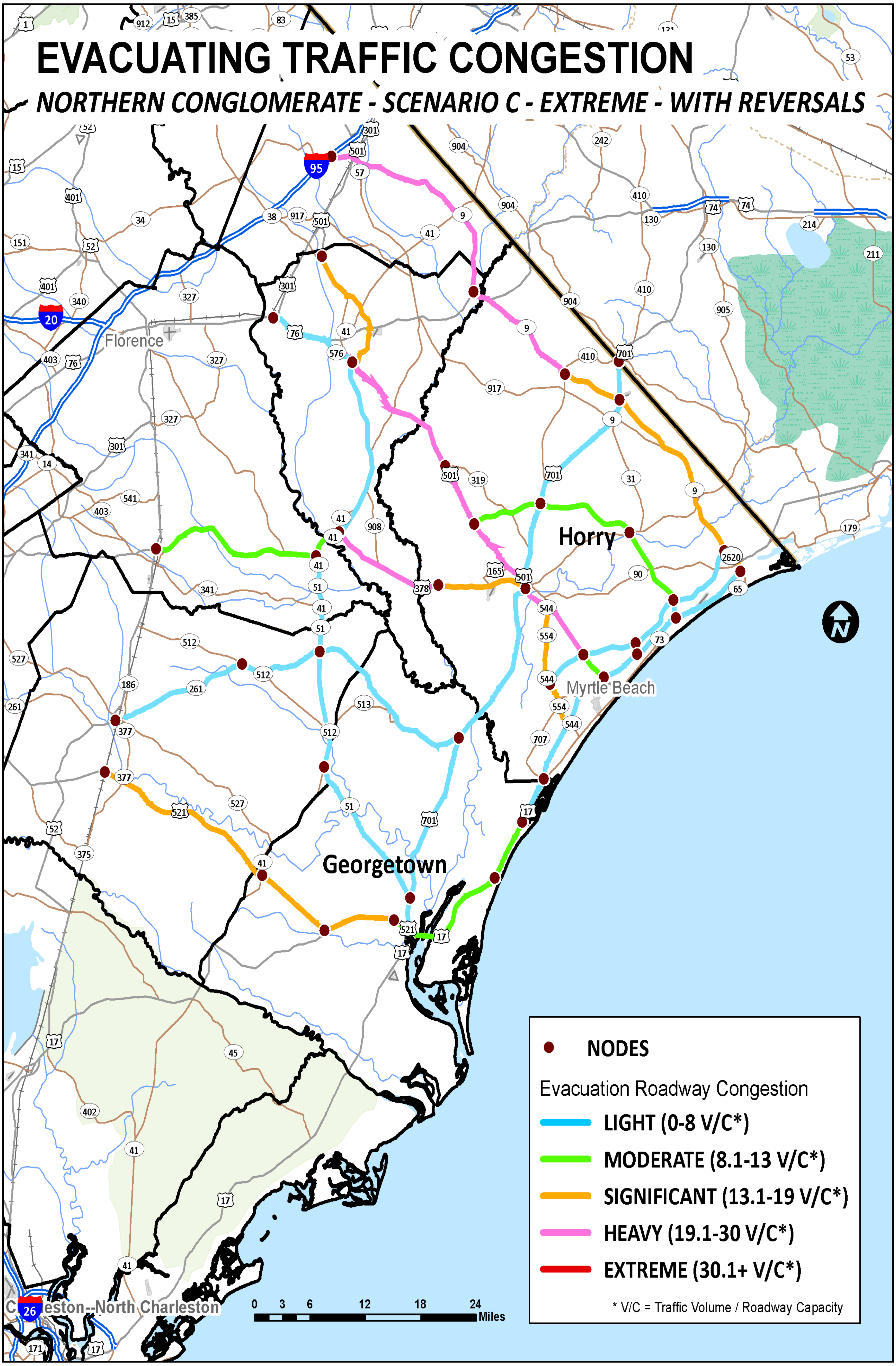

Figure 9: Worst Case Evacuating Traffic Congestion – Northern Conglomerate / With Reversals

Table 21: Worst Case Evacuation Network Congestion (2011 Base Year Evacuating Traffic by Vehicle)

			Scenario A				Scenario B				Scenario C			
County	Critical Roadway Segments	Directional Service Volume	Evac Veh Low Occ	Evac Veh Med Occ	Evac Veh High Occ	Evac Veh Ext Occ	Evac Veh Low Occ	Evac Veh Med Occ	Evac Veh High Occ	Evac Veh Ext Occ	Evac Veh Low Occ	Evac Veh Med Occ	Evac Veh High Occ	Evac Veh Ext Occ
Horry	US 17 sb into Georgetown County	1,600	2,032	2,709	4,064	4,741	3,717	4,550	6,216	7,049	4,214	5,047	6,714	7,546
	US 378 wb out of Conway* NO REVERSAL	1,800	3,025	3,909	5,711	7,301	4,848	6,092	8,274	9,788	7,654	10,318	12,573	12,713
	US 378 wb inland 2 lane section* NO REVERSAL	1,100	3,081	3,985	5,823	7,356	4,952	6,212	8,437	9,913	7,793	10,520	12,819	12,872
	US 501 nb e of SC 31/Carolina Bays Pkwy	2,400	7,450	10,684	17,164	21,600	10,650	14,586	21,729	25,800	11,900	18,784	26,008	27,150
	US 501 e of SC 544 at outlet mall area	1,700	8,556	12,280	19,728	23,453	12,662	16,765	24,976	29,082	17,439	21,591	29,894	34,048
	US 501 from SC 544 to Conway* NO REVERSAL	1,700	12,988	17,869	27,631	32,514	20,374	25,953	37,116	42,697	32,480	38,164	49,532	55,217
	US 501 from Conway to Conway Bypass* NO REVERSAL	1,800	10,946	15,034	23,151	25,765	17,423	19,853	28,737	34,574	28,421	27,247	36,556	46,059
	US 501 from Conway Bypass through Aynor* NO REVERSAL	1,800	17,021	24,054	38,071	43,177	25,947	33,006	48,409	55,208	38,805	42,121	57,777	68,663
	US 501 from Aynor to SC 576 at Marion* NO REVERSAL	2,200	18,812	28,063	44,416	44,824	28,540	38,507	56,478	57,677	42,841	49,142	67,406	72,402
	Conway Bypass	2,800	6,396	9,380	15,346	18,329	8,957	12,138	18,504	21,686	10,865	14,076	20,498	23,710
	SC 9 at Longs	1,800	7,075	9,142	13,272	15,338	9,233	11,484	15,985	18,237	12,204	14,539	19,207	21,542
	SC 9 from Green Sea to Nichols	1,200	7,100	9,233	13,405	15,500	9,300	11,599	16,145	18,400	12,300	14,684	19,399	21,700
	US 701 nb out of county	1,200	1,537	2,095	3,210	3,768	2,293	2,915	4,161	4,784	2,989	3,623	4,892	5,527
	US 17 nb into NC	2,000	1,176	1,559	2,325	2,708	1,435	1,850	2,680	3,095	1,835	2,265	3,126	3,557
	SC 544 from Socastee to US 501	1,700	4,432	5,589	7,902	9,061	7,712	9,188	12,140	13,615	15,041	16,573	19,637	21,170
	Grissom Pkwy at SC 31/Carolina Bays Pkwy	1,000	1,974	2,916	4,798	5,739	3,184	4,218	6,286	7,320	3,795	4,835	6,917	7,958
	SC 31/Carolina Bays Pkwy sb at US 501	3,000	2,200	3,236	5,325	6,300	3,500	4,682	6,977	8,000	4,100	5,367	7,678	8,700
	SC 31/Carolina Bays Pkwy nb at SC 22	3,000	3,660	5,377	8,811	10,528	5,275	7,141	10,874	12,741	6,775	8,659	12,428	14,312
Georgetown	US 17 Bridge off Waccamaw Neck	1,700	4,819	6,011	8,397	9,590	7,838	9,118	11,678	12,957	9,041	10,321	12,880	14,160
	Church St at Fraser St in Georgetown	1,500	4,964	6,170	8,584	9,791	8,014	9,308	11,896	13,189	9,248	10,542	13,128	14,423
	US 521 from Georgetown to Alt US 17	1,700	8,056	10,569	14,096	14,676	13,732	16,610	20,612	21,349	16,565	19,666	23,692	24,227
	US 521 wb west of Andrews	1,200	7,079	9,257	12,360	12,686	11,748	14,509	18,040	18,113	14,188	17,135	20,686	20,592
	Alt US 17 sb at SC 41	1,000	977	1,313	1,737	1,990	1,985	2,100	2,572	3,236	2,377	2,531	3,006	3,635
	SC 261 wb at Hemingway	1,000	408	1,094	1,500	812	1,013	2,020	2,522	1,556	1,222	2,369	2,873	1,770
	SC 41/SC 51 nb at Kingsburg	700	723	1,854	2,549	1,397	1,520	3,010	3,815	2,355	1,851	3,540	4,349	2,692
Regional	*US 501-SC 544 to Conway WITH 544 ENHANCEMENT	2,700	12,988	17,869	27,631	32,514	20,374	25,953	37,116	42,697	32,480	38,164	49,532	55,217
	*US 501 Conway to Conway Bypass WITH REVERSAL	1,800	8,130	11,137	17,149	20,155	12,568	15,955	22,735	26,125	18,194	21,663	28,599	32,068
	*US 501 Conway Bypass through Aynor WITH REVERSAL	2,850	14,205	20,045	31,726	37,567	21,092	27,505	40,341	46,759	28,578	35,101	48,147	54,673
	*US 501 Aynor to Marion WITH REVERSAL	3,200	15,700	22,150	35,057	39,000	23,200	30,393	44,577	48,850	31,550	38,787	53,203	57,650
	*US 378 wb out of Conway WITH 544 ENHANCEMENT	1,800	5,790	7,549	11,030	12,870	9,600	11,766	15,981	18,130	17,700	19,927	24,282	26,530
	*US 378 wb 2 lane section WITH 544 ENHANCEMENT	1,100	5,897	7,664	11,198	12,967	9,807	11,946	16,224	18,362	18,020	20,231	24,652	26,863

G) Evacuation Traffic from Other States and Regions

One of the task items required in this study was an examination of potential regional through traffic that the Northern Conglomerate might experience during an evacuation. Given the location of the Northern Conglomerate and features of the South Carolina Highway Patrol latest hurricane evacuation traffic control plan, this will not be a big issue for the study area. However I-95 as well as US 52 could receive evacuation traffic from the Southern and Central Conglomerates, Georgia, and North Carolina for certain storm tracks (e.g. Hurricane Floyd, 1999). Using data from the last hurricane studies prepared for these states and regions, Table 22 shows the potential of traffic from each jurisdiction on the roadway which will be impacted. These numbers will need to be updated once new studies are completed.

Table 22: Regional Impacting Traffic to Northern Conglomerate

Regional Through Evacuation Traffic Impacting Northern Conglomerate, South Carolina Number of Vehicles by Contributing Region/State					
I-95 nb thru study area	**SC - South Conglomerate**	**SC – Central Conglomerate**	**Georgia**	**North Carolina**	**Totals by Scenario**
Scenario A low tourist occupancy	1,770	5,500	2,760	0	**10,030 vehicles**
Scenario A high tourist occupancy	2,760	6,680	3,540	0	**12,980 vehicles**
Scenario B low tourist occupancy	4,450	7,810	5,985	0	**18,245 vehicles**
Scenario B high tourist occupancy	5,590	9,500	6,930	0	**22,020 vehicles**
Scenario C low tourist occupancy	6,550	12,470	7,010	0	**26,030 vehicles**
Scenario C high tourist occupancy	7,780	14,330	7,950	0	**30,060 vehicles**
I-95 sb thru study area					
Scenario A low tourist occupancy	0	0	0	1,160	**1,160 vehicles**
Scenario A high tourist occupancy	0	0	0	1,600	**1,600 vehicles**
Scenario B low tourist occupancy	0	0	0	1,840	**1,840 vehicles**
Scenario B high tourist occupancy	0	0	0	1,950	**1,950 vehicles**
Scenario C low tourist occupancy	0	0	0	2,210	**2,210 vehicles**
Scenario C high tourist occupancy	0	0	0	2,670	**2,670 vehicles**
US 52 nb thru study area					
Scenario A low tourist occupancy	0	1,375	0	0	**1,375 vehicles**
Scenario A high tourist occupancy	0	1,670	0	0	**1,670 vehicles**
Scenario B low tourist occupancy	0	1,950	0	0	**1,950 vehicles**
Scenario B high tourist occupancy	0	2,375	0	0	**2,375 vehicles**
Scenario C low tourist occupancy	0	3,120	0	0	**3,120 vehicles**
Scenario C high tourist occupancy	0	3,580	0	0	**3,580 vehicles**

IV. Study Findings

IV. Study Findings

A) Clearance Times

The evacuation modeling process, as with all modeling efforts, transforms complex real world events into a series of numbers. The modeling approach used in this study has been accepted nationally and validated through numerous post storm assessments, but like any modeling process, it involves a simplification of complex real world systems. Evacuation modeling results – including clearance times – are only as good as the available inputs. The model relies on objective data and assumptions related to resident populations, expected evacuation behaviors, roadway characteristics and other inputs. It also includes more subjective components, including traffic routing and destination choices. All of the data is subject to change over time due to changing conditions. Model results that are ten or more years old would be less accurate than more recently estimated results.

For evacuations that have occurred over the last 25 years throughout the coastal United States, real time traffic count data has been reviewed to see how roadway capacity fluctuates during hurricane evacuations. Based on this knowledge and experience in the modeling process, the evacuation has been divided into four quarters. During the first quarter of the evacuation, it is assumed that roadway segments will be able to process vehicles at near maximum directional capacity. As the evacuation progresses, vehicle flows diminish during the second and third quarters as more evacuees try to load the road network and the available capacity is overwhelmed. In the fourth quarter of the evacuation, the modeling assumes a return to near full capacity. This approach has yielded the development of valid clearance times that have been tested favorably by real events. Service volumes are diminished by 15% in the second quarter of the evacuation and reduced another 15% in the third quarter of the evacuation. In the fourth quarter, service volumes return to the starting value as observed in multiple evacuations.

Once the steps in the modeling process have been undertaken, it is possible to generate estimates of hurricane evacuation clearance times. The roadway network functions like a pipe and the vehicles passing like water through that conduit. In areas where the "pipe" is narrow, where the roadway has a low service volume and evacuation traffic volumes are higher, clearance times will be higher. The worst possible bottleneck that a county's traffic must pass through before reaching its external destination determines its clearance time. This point may sometimes be in another county.

IV. Study Findings

Clearance time is the period needed from when the first vehicle leaves its zone of origin to the point where the last evacuating vehicles reaches an assumed point of safety which in the case of the Northern Conglomerate is I-95. Clearance time estimates include several components, including mobilization time, travel time and queuing delay time. The mobilization time is the time required by evacuees to prepare for evacuation and enter the road network, travel time is the time needed to travel along the road network and queuing delay time is the cumulative time associated with all stops caused by traffic congestion. Clearance time calculations recognize that some evacuees will still be preparing to leave while others have already commenced evacuation.

Background traffic for each critical roadway segment was also incorporated based on the average annual daily trips (AADT) collected for these nodes from data from SCDOT. Following the approaches used in other evacuation studies, the AADT was multiplied by a peak hour travel and directional factor to calculate levels of background traffic that might be present at the start of an evacuation. For example, if a roadway in the study area carries 30,000 vehicles on a daily basis, that figure would be multiplied by 55% directional factor and a 12% peak hour percentage to come up with a starting background traffic number of 1,980 vehicles. These vehicles have to be processed through the network in addition to the expected numbers of evacuating vehicles.

Clearance time estimates are also influenced by the rapidity of evacuation response by the evacuating population, or how quickly the vulnerable population will respond to an evacuation order or advisory. This factor directly impacts how quickly evacuees try to load the road network. Behavioral data from past hurricane evacuation research demonstrates that mobilization and actual departures of the evacuating population can occur over a very brief time, or over a period of many hours. The evacuation response curves presented in Figure 10 reflect slow (long response), medium, fast (rapid response) and immediate (rapid response) responses which are designed to include the range of mobilization times that may be experienced in a hurricane evacuation scenario. The behavioral response curves shown in Figure 10 are generalized scenarios that have been used in past HES efforts and were originally based on work done by Dr. Jay Baker of Hazards Management Group. Every evacuation has a different response curve/footprint.

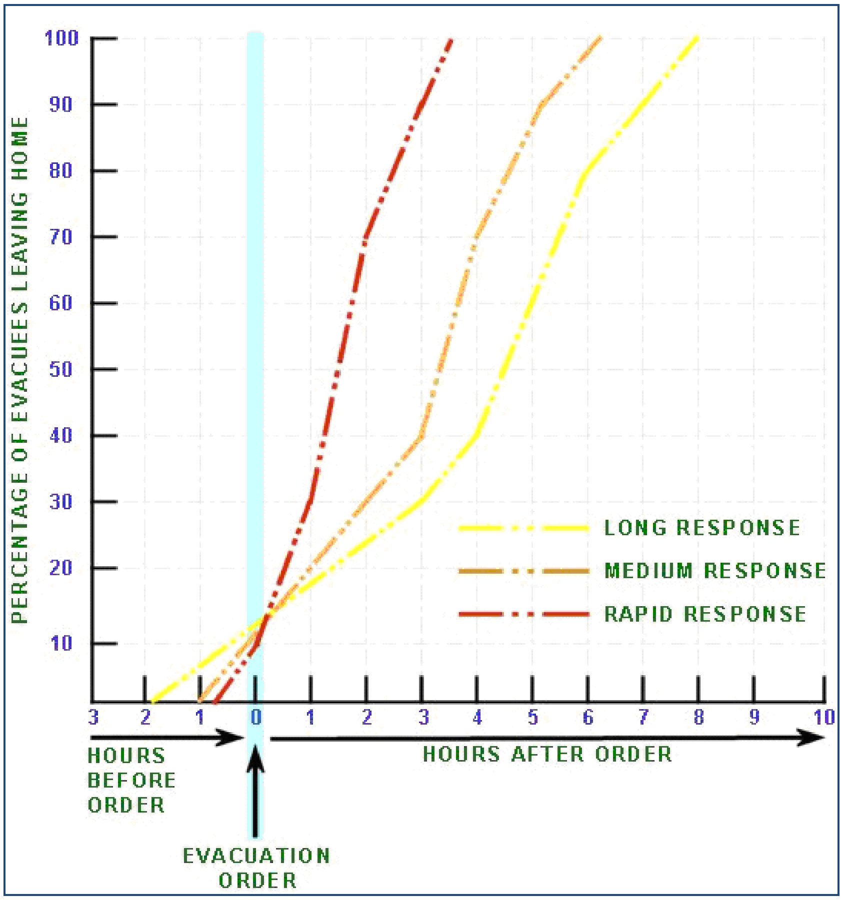

Figure 10: Generalized Evacuation Response Curve for Clearance Time Testing

While these basic assumptions were used in this study, other factors may affect evacuation response rates, including the timing of a hurricane evacuation order and the urgency of messages communicated by The Weather Channel® and local news media. Communicating evacuation instructions to people when they can be reached is an important factor. Hurricanes are by nature unpredictable. Storms can rapidly intensify or increase their forward motion. Windows of opportunity exist for enhanced or more rapid evacuation responses from the public. During weekdays, evacuation orders issued in the early morning (5 am – 7 am) or during dinner hours (5 pm – 7 pm) may reach a broader audience and result in more rapid responses although during the weekend when less people are at work there may be less of a difference. On any day of the week, the issuance of an evacuation order at 3 am when people are generally asleep may also result in a slower evacuation response rate than one issued at 7 am as people are beginning to start their day.

A wide range of clearance times are provided for each storm scenario. These times are designed to guide emergency managers in making the critical decision of when to call for an evacuation. While the model can produce times that include 6 minute variations (tenths of hours), this level of differentiation is not particularly relevant to decision makers who will be basing their actions on 6 hour National Hurricane Center advisory periods.

Clearance times have been developed based on extreme (85%), high (70%), medium (50%) and low (20%) tourist occupancy rates. Seasonal/hotel occupancies were varied between the lowest occupancy that might be present at the start of an evacuation (November weekday) and the most extreme scenario where 85% of the units are still occupied at the start of an evacuation of the general population. With 83% being the highest rate documented by the Chamber of Commerce during the hurricane season and assuming at least 15% of the tourists will flee or cancel their trip before an evacuation begins, 85% as an extreme test scenario seems quite reasonable if not overly conservative with a large percentage of seasonal condos and timeshares in foreclosure. Also the seasonal unit numbers in the ATM are quite robust and include RV sites/campgrounds (not just hotel/motels). The occupancy rates were developed based on hotel / motel occupancy rates that are typical throughout the hurricane season.

Transportation analyses often include only two variables; a high season tourist level, representing the average occupancy rate during the height of tourist season (which would be in the summer months in South Carolina), as well as a low season tourist level, which represents the average occupancy during the winter months. Even on special holidays such as July 4, the occupancy rates will not be 100% <u>at the start of an evacuation.</u> The ATM developed for the project actually allows the user to incorporate the actual tourist occupancy at the start of an evacuation.

Clearance times were provided for a slow (9 hour), medium (7 hour), rapid (4 hour), and immediate (4 hour) mobilization response time. Clearance time runs are generated based on a range of variables; different hurricane intensities, levels of background traffic, different tourist occupancy levels, and the rapidity of response by evacuees.

Based on the three storm intensity scenarios, four response rates and four tourist occupancy levels, and various SCDOT reversal concepts, 144 different scenarios were tested and reported for the two counties in the Northern Conglomerate. Table 23 shows the clearance times for each scenario by county.

Given the location of the Northern Conglomerate relative to other coastal areas that will produce evacuating vehicles for the same storm, the impact of evacuating traffic from outside of the study area will be minimal at best. While the additional traffic from the Central Conglomerate and southeastern North Carolina may slightly increase segment specific clearance times along I-95 in some scenarios, the additional traffic will not affect the worst-case clearance times at the bottlenecks determining the county-clearance times for the study area.

A listing of the clearance times by critical roadway segment for each response (slow, medium, and fast) is located in Table 24.

Critical segments along the roadway network will control the flow of evacuation traffic. The following roadways are the most critical roadway segments in the Northern Conglomerate study area:

- SC 501 from Aynor to Marion
- SC 501 from SC 544 to Conway
- SC 501 from Carolina Forest to the Coastal Carolina University area
- US 378 westbound to Lake City (2 lanes sections)
- US 521 Andrews to Manning (2 lanes sections)
- SC 9 Green Sea to Nichols

As seen in Figures 8 and 9, the potential evacuation traffic congestion by roadway segment for the worst case scenario (extreme tourist occupancy – Scenario C) is illustrated for Horry and Georgetown Counties. Estimated congestion levels were compared to the roadway network service volume. The highest segments, in red, are assumed to have higher levels of congestion and therefore are considered the “critical links” for a particular scenario. These segments may vary depending on storm intensity; therefore officials should not concentrate on any one particular location but rather ensure the most extreme locations are monitored for each event.

Table 23: Clearance Times

County	Response	Scenario A				Scenario B				Scenario C			
		Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ	Low Occ	Med Occ	High Occ	Extreme Occ
Horry (with 501 reversal and 544 enhancement plan)	Slow	11	14	17	18	14	18	21	22	22	26	29	31
	Medium	9	12	15	16	12	16	19	20	20	24	27	29
	Fast	8	11	14	15	11	15	18	19	19	23	26	28
	Immediate	7	10	13	14	10	14	17	18	18	22	25	27
Horry (no 501 reversal or 544 enhancement plan)	Slow	15	21	28	30	20	27	35	38	28	35	43	46
	Medium	13	19	26	28	18	25	33	36	26	33	41	44
	Fast	12	18	25	27	17	24	32	35	25	32	40	43
	Immediate	11	17	24	26	16	23	31	34	24	31	39	42
Georgetown	Slow	11	14	16	17	16	19	21	22	18	21	24	25
	Medium	9	12	14	15	14	17	19	20	16	19	22	23
	Fast	8	11	13	14	13	16	18	19	15	18	21	22
	Immediate	7	10	12	13	12	15	17	18	14	17	20	21

Table 24: Clearance Times by Critical Roadway Segment

County	Critical Roadway Segment	Scenario A Low Occ	Scenario A Med Occ	Scenario A High Occ	Scenario A Ext Occ	Scenario B Low Occ	Scenario B Med Occ	Scenario B High Occ	Scenario B Ext Occ	Scenario C Low Occ	Scenario C Med Occ	Scenario C High Occ	Scenario C Ext Occ
Horry	US 17 sb into Georgetown County	5	5	6	7	6	7	8	8	6	7	8	9
	US 378 wb out of Conway* **NO REVERSAL**	5	6	7	8	6	7	8	9	8	10	11	11
	US 378 wb inland 2 lane section* **NO REVERSAL**	5	6	8	10	7	9	11	12	10	13	15	15
	US 501 nb e of SC 31/Carolina Bays Pkwy	7	8	11	13	8	10	13	15	9	12	15	16
	US 501 e of SC 544 at outlet mall area	10	12	17	19	12	15	20	23	16	18	23	26
	US 501 from SC 544 to Conway* **NO REVERSAL**	12	15	21	24	16	20	27	31	24	28	35	38
	US 501 from Conway to Conway Bypass* **NO REVERSAL**	10	12	17	19	14	15	21	24	20	20	25	31
	US 501 from Conway Bypass through Aynor* **NO REVERSAL**	13	17	25	28	18	22	31	36	26	28	37	44
	US 501 from Aynor to SC 576 at Marion* **NO REVERSAL**	12	16	24	24	16	21	30	31	23	27	36	38
	Conway Bypass	6	7	9	11	7	8	11	12	8	9	11	13
	SC 9 at Longs	7	8	10	12	8	9	12	13	10	11	14	15
	SC 9 from Green Sea to Nichols	9	11	15	16	11	13	17	19	14	16	20	22
	US 701 nb out of county	4	4	5	6	5	5	6	7	5	6	7	7
	US 17 nb into NC	3	3	4	4	3	3	4	4	3	4	4	4
	SC 544 from Socastee to US 501	7	8	9	10	9	10	12	13	14	15	17	18
	Grissom Pkwy at SC 31/Carolina Bays Pkwy	6	7	9	10	7	8	10	11	8	9	11	12
	SC 31/Carolina Bays Pkwy sb at US 501	3	4	4	5	4	4	5	5	4	4	5	6
	SC 31/Carolina Bays Pkwy nb at SC 22	4	4	6	6	4	5	6	7	5	6	7	8

Table 24: Clearance Times by Critical Roadway Segment (continued)

County	Critical Roadway Segment	Scenario A Low Occ	Scenario A Med Occ	Scenario A High Occ	Scenario A Ext Occ	Scenario B Low Occ	Scenario B Med Occ	Scenario B High Occ	Scenario B Ext Occ	Scenario C Low Occ	Scenario C Med Occ	Scenario C High Occ	Scenario C Ext Occ
Georgetown	US 17 Bridge off Waccamaw Neck	6	6	8	9	7	8	10	11	8	9	11	11
	Church St at Fraser St in Georgetown	7	8	10	10	9	10	12	13	10	11	13	14
	US 521 from Georgetown to Alt US 17	8	9	11	13	12	13	16	17	14	15	17	19
	US 521 wb west of Andrews	9	11	14	15	14	15	19	20	16	18	21	23
	Alt US 17 sb at SC 41	4	4	4	5	4	5	5	5	5	5	6	6
	SC 261 wb at Hemingway	3	4	4	4	4	5	5	5	5	5	6	6
	SC 41/SC 51 nb at Kingsburg	5	5	6	7	6	7	8	9	7	8	9	10
Regional	*US 501-SC 544 to Conway **WITH 544 ENHANCEMENT**	9	11	14	16	12	14	18	21	16	19	23	26
	*US 501 Conway to Conway Bypass **WITH REVERSAL**	8	10	14	16	11	13	17	19	14	16	21	23
	*US 501 Conway Bypass thru Aynor **WITH REVERSAL**	8	10	14	17	10	13	18	20	13	16	21	23
	*US 501 Aynor to Marion **WITH REVERSAL**	8	10	14	16	10	13	17	19	13	16	20	22
	*US 378 wb out of Conway **WITH 544 ENHANCEMENT**	7	8	10	11	9	11	13	14	14	15	18	19
	*US 378 wb 2 lane section **WITH 544 ENHANCEMENT**	8	10	13	15	12	14	18	20	20	22	27	29

IV. Study Findings

It is critical to recognize that clearance times are predicated upon all evacuation movements occurring before the advent of sustained tropical storm force winds. Typically storm surge effects which cut off roadways occur well after the arrival of sustained tropical storm winds. Based on this modeling assumption, evacuation movements occurring within the prescribed clearance times would not be impacted by surge related roadway flooding.

While the model for the Northern Conglomerate Study Area transportation analysis is based on a typical storm scenario, as illustrated in Figure 11, it is critical that emergency managers monitor storm conditions and National Weather Service advisories to determine if information regarding a higher than expected or more rapid rise of storm surge is predicted.

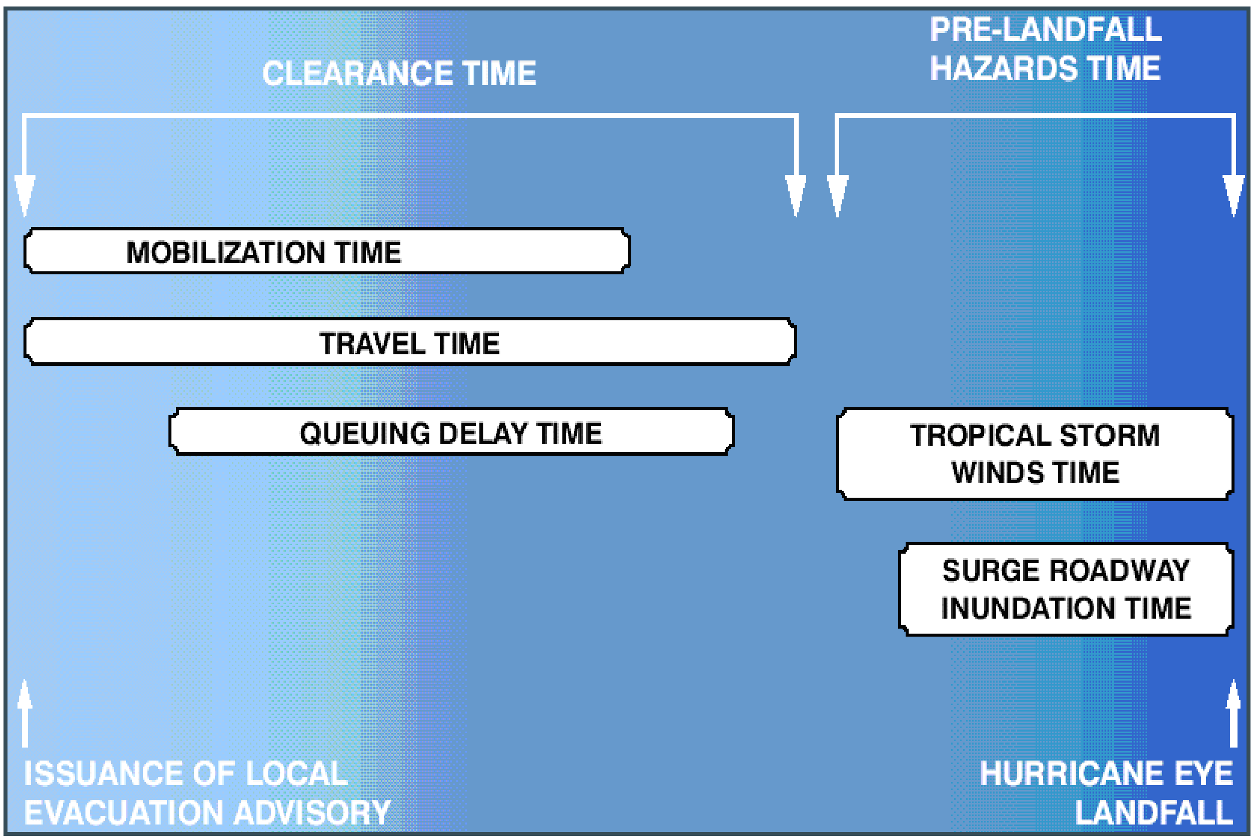

Figure 11: Components of Clearance Time

IV. Study Findings

Table 25 abbreviates the more expansive data provided in Tables 22 and 23 by showing only the best and worst clearance time for each evacuation scenario as a range regardless of response rate or tourist occupancy.

Table 25: Clearance Times Ranges

County	Scenario A	Scenario B	Scenario C
Horry (with 501 reversal and 544 enhancement plan)	7 to 18 hours	10 to 22 hours	18 to 31 hours
Horry (no 501 reversal or 544 enhancement plan)	11 to 30 hours	16 to 38 hours	24 to 46 hours
Georgetown	7 to 17 hours	12 to 22 hours	14 to 25 hours

Variable Accuracy and Confidence Limits

The evacuation modeling process, as with all modeling efforts, transforms complex real world events into a series of numbers. The modeling approach used in this study has been accepted for decades and validated through numerous post storm assessments, but, like any modeling process, it involves a radical simplification of complex real world systems and as such may include an inherent margin of error. The transportation model employed in this study relies on sets of objective data on populations, behaviors, roadway characteristics and other elements. It also includes subjective components, including routing and destination choices. All of the data is subject to change over time due to changing conditions. Model results that are ten or more years old would be less accurate than more recently estimated results.

Efforts have been made to obtain the most current and best available input data, with sources properly identified in the report. These data have been compared, where possible, to data obtained or derived from other sources. In instances where two sets of data were available, the contractor relied on their 30+ years of experience in evacuation modeling to assure the data used in the analysis was appropriate for use in the modeling process and appeared to be in the correct range. Reasonable variations in demographic inputs will have relatively minor impact on clearance times, although some changes should be expected. While the clearance time estimates provided in the study are fully supported by the contractor, a margin of error may exist due to the range of different modeled inputs as well as actual conditions leading up to an evacuation.

IV. Study Findings

Evacuation modeling results – including clearance times – are only as good as the available inputs. The modeling approach used in this study relies upon the most current SLOSH model surge results in developing risk-based evacuation zones. According to NOAA, the SLOSH model is accurate to +/- 20 percent. As an example, if the model calculates a peak 10 foot storm surge, the observed peak could range from 8 to 12 feet. The modeling approach also relies heavily on US Census data. While touted as being more accurate than the 1990 Census, the US Census Bureau acknowledges variations in the accuracy of its published data by as much as 10 percent for some variables. A range of behavioral data was used in this study, including the recently completed USC survey, as well as data from past analyses. Behavioral studies commonly provide results that are accurate to within 10% of actual values depending on sample size and response rates. Finally, roadway service volumes fluctuate greatly during an evacuation, sometimes varying by as much as 30 percent less than the theoretical maximum. The transportation analysis contractor is 95 percent confident that the clearance times fall within the accuracy limits of the key inputs stated above.

B) Traffic Control Measures

In the aftermath of Hurricanes Hugo and Floyd, SCDOT in collaboration with state and local law enforcement and emergency management officials, worked to address shortcomings identified during previous evacuations. Reverse lane strategies, in-route evacuee assistance, and public information campaigns have been developed to facilitate future evacuations. New roadways such as the Carolina Bays Parkway facility and Conway Bypass have been built which also serve evacuation movements as well.

The movement of evacuating vehicles during a hurricane evacuation requires extensive traffic control efforts to make maximum use of the roadway capacity and to expedite a safe escape from hurricane hazards. Directing resources to areas that have been identified as potential congestion “hot spots” may help alleviate congestion. Capital improvement to these segments, as well as to the critical bottlenecks that influence the regional clearance time estimates, may reduce overall evacuation clearance times.

Some additional recommendations concerning traffic control are as follows:

- Where the State and counties have sufficient personnel resources, officers should be stationed at critical intersections to facilitate traffic flow; where intersections will continue to have signalized control, signal patterns providing the most "green time" for westbound evacuation travel should be activated.

- If possible, arrangements should be made with tow truck operators so that they are pre-positioned along key travel corridors and critical roadway facilities such as bridges.

- The state and counties should continue to develop their GIS based dashboard for statewide evacuation and sheltering including a monitoring system which would monitor travel flow at key locations, report traffic tie-ups and shelter and hotel availability to the general public as they evacuate.

- High level bridges must be monitored for early wind vulnerability as sustained tropical storm winds will arrive earlier on these structures than at ground level; trucks, RV's and other high profile vehicles will be especially vulnerable to these conditions.

- SCDOT should continue, and where possible, expedite the improvements to US 378 between Conway and Lake City.

- New evacuation traffic control ideas should be researched for feasibility including easing SC 9 inland bottlenecks and the diversion of Carolina Forest evacuees to the Conway Bypass.

Roadway measures can be classified into three groups:

- <u>Structural Improvements</u>. Including lane widening, designed to increase roadway capacity.

- <u>Maintenance of Traffic</u>. Including signage, designed to improve the maximum Level of Service D hourly service volume.

- <u>Operational Interventions</u>. Including implementing traffic diversions or executing a contra flow plan, which will improve service volumes on specific facilities or route traffic along less utilized facilities.

Specific traffic control measures and roadway modifications at the critical roadway segments identified may help alleviate anticipated congestion in these areas and subsequently improve overall local and / or regional clearance times.